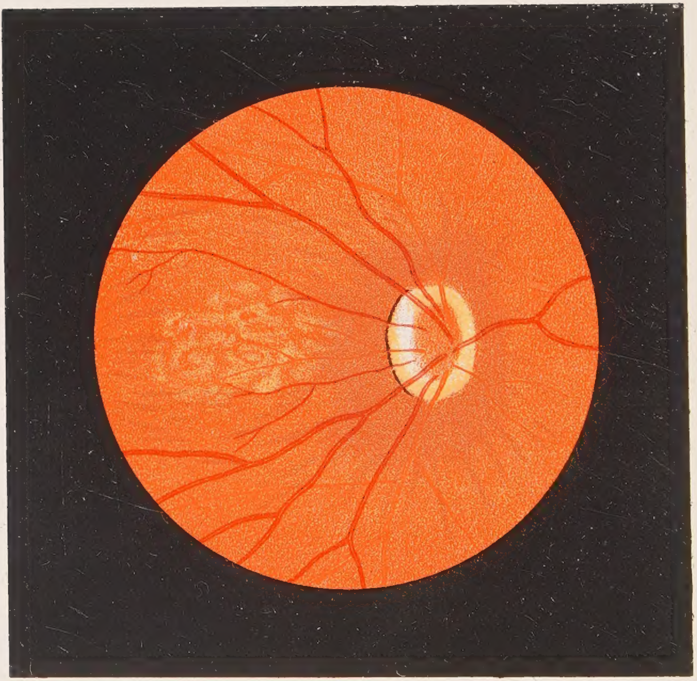
REFRACTION OF THE EYE

ERNEST CLARKE

THE ERRORS OF ACCOMMODATION AND REFRACTION OF THE EYE



THE FUNDUS OF THE RIGHT EYE OF A MYOPE.

The amount of myopia is 9D, and correction gives normal vision.

The retinal vessels are very straight, and they are seen to curl over the tilted nasal margin of the disc.

The "myopic crescent," instead of being limited to the outer or temporal side of the disc, is seen to surround it.

[The fellow eye is much the same, only the changes at the macula are more marked, and vision is only $\frac{6}{12}$].

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THE ERRORS OF ACCOMMODATION AND REFRACTION OF THE EYE

AND THEIR TREATMENT

A Handbook for Students

BY

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MDCCCCIII

PREFACE

I HAVE tried to make the following pages, based on lectures delivered at the Central London Ophthalmic Hospital and the Medical Graduates' College, essentially practical, and have omitted all matter unnecessary for the busy practitioner or overburdened student.

Recognising the importance of asthenopia in medical treatment, I have given the subject a prominent place throughout the book.

ERNEST CLARKE.

CHANDOS STREET,
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THE

REFRACTION OF THE EYE

CHAPTER I.

OPTICS.

Light. — Light is now considered to be an electromagnetic phenomenon. It is propagated in straight lines which diverge from any luminous point. The propagation is produced by ether waves which are horizontal—*i.e.*, at right angles to the path of light. The velocity of light is, in round numbers, 186,000 miles per second, and is appreciably retarded in passing through a denser medium. Rays of light coming from any luminous point distant 6 metres from the eye, may be assumed, for all practical purposes, to be parallel.

Light is absorbed, refracted, or reflected.

Refraction of Light.—A ray of light passing from a rarer into a denser transparent medium, if it be perpendicular to the surface, and the boundaries of the medium be parallel, will pass out of the denser medium in the same straight line (Fig. 1, L), the only effect upon it being a retardation. If the ray enter the denser medium other than perpendicularly, or if the boundaries of the medium be not parallel, the ray is bent or refracted.

A simple illustration will explain this.

Explanation of Refraction.—As ether waves are horizontal, if a beam of light enter a denser medium obliquely, one end of the wave will enter the denser medium before the other, and consequently be retarded earlier. Let A B C D (Fig. 1) be a denser medium, with parallel boundaries, and N O P Q the beam of light.

The wave front will reach Q before it reaches R, and it will at once be retarded, and as it thus travels more slowly from Q to S than from P to R (which is outside the denser

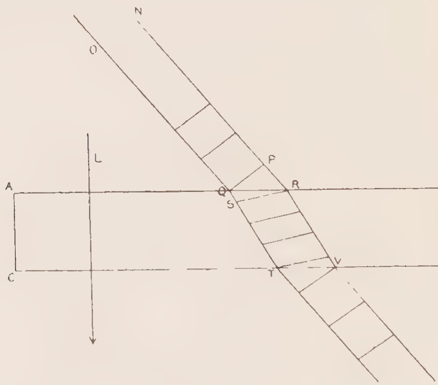


FIG. 1.

medium), the beam must be swung round so that it is bent or refracted on entering the denser medium.

Across the denser medium the whole wave front is equally affected, so that the beam passes across in a straight line, and if the sides of the medium be parallel, the converse happens, and it is again bent, on passing out, the incident and the emergent rays being parallel.

Let this be applied to the case of, for example, a prism where the sides of the denser medium are not parallel. Suppose A B C (Fig. 2) to be a triangular strip of velvet pasted on a smooth board, and suppose *d* to be two

small wheels connected by an axle in such a way that each wheel can turn independently of the other. Roll the wheels up to the velvet triangle; the lower or right wheel will pass on to the velvet at *e* before the left wheel reaches it, and as the velvet will retard its progress, it will turn now more slowly than the left wheel, so that the pair of wheels will be slewed round towards the base of the triangle. When the left wheel enters on the velvet at *f*, its progress will be the same as the other wheel, and the pair of wheels will cross the velvet now in a straight line; when it reaches *m*, the left or upper wheel will

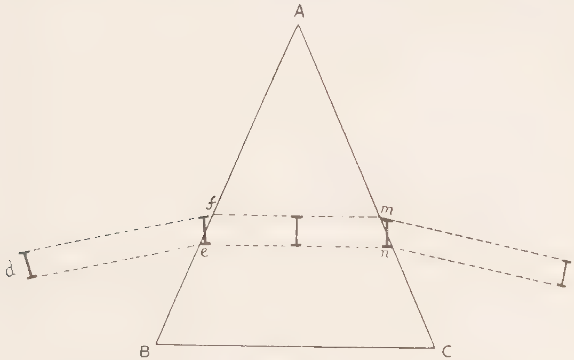


FIG. 2.

leave the velvet earlier, and will consequently travel more rapidly, and will again swing the pair round, so that in the transit across the triangle the pair of wheels have been bent towards the base.

Light behaves exactly in this manner, and in passing through a prism it is bent or refracted towards the base.

In ophthalmology a prism means a wedge of glass bounded by plane surfaces which are inclined to each other at an angle, such angle being the angle of the prism (B A C, Fig. 2). The side opposite the angle is called the *base* of the prism (see Appendix).

Place two such prisms with their bases in contact, and we have roughly a bi-convex lens (Fig. 3, A), and rays of light passing through it are bent towards the base of the prisms—*i.e.*, the centre of the lens; in other words, they converge. If the prisms have their apices in contact, we have a bi-concave lens (Fig. 3, B), and the rays are bent towards the bases—*i.e.*, outwards—and diverge.

Spherical Lenses.—Besides the bi-convex (Fig. 3, A) and bi-concave lenses (B) there are plano-convex (C), plano-concave (D), converging concavo-convex or converging meniscus (E), and diverging concavo-convex or diverging meniscus (F). Rays of light passing obliquely

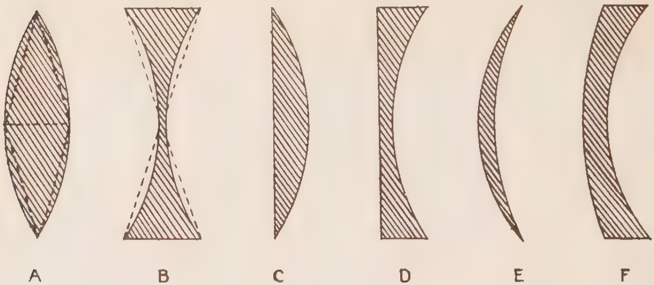


FIG. 3.

through any of these forms of lenses are refracted or bent towards the *thickest* part of the lens.

The principal axis is a line drawn through the optical centre at right angles to the lens (Fig. 4, A O), and rays passing through this are not refracted; all other lines passing through the optical centre not at right angles to the lens are called secondary axes (Fig 5, A*a*).

Rays passing along the secondary axes are refracted, but as the emergent and the incident rays are in the same direction, and the refraction in low-power lenses is very slight, the refraction can be ignored, and the rays assumed to pass along in a straight line.

Convex Lenses.—Parallel rays passing through a convex lens unite on the opposite side of the lens at a point called the principal focus (P F, Fig. 4).

At the principal focus an inverted real image of the object is formed. Let A B (Fig. 5) be an object at infinite

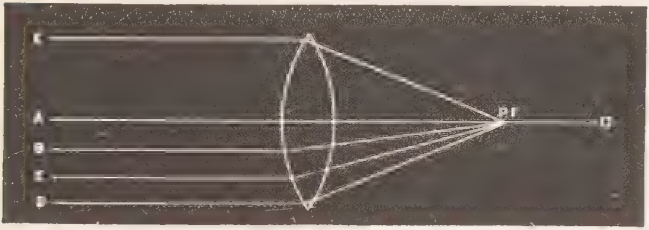


FIG. 4.

distance from the lens. Any ray passing from the point A through the optical centre of the lens C will be unrefracted (*vide supra*), and the image of A will be somewhere on this line on the other side of the lens, let it be at *a*; all other rays passing from A will be refracted on

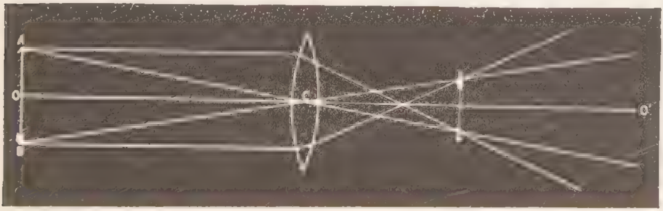


FIG. 5.

passing through the lens, and will focus at *a*. In the same manner an image of B is formed at *b*, and all other points between A and B will form an image between *a* and *b*, so that we get an inverted image *a b* of A B formed at the principal focus of the lens.

The distance between the principal focus and the optical centre is called the principal focal distance; it is positive, and convex lenses are known by the plus sign : +.

Rays passing from the principal focus (P F) through the lens emerge as parallel rays on the opposite side (Fig. 4).

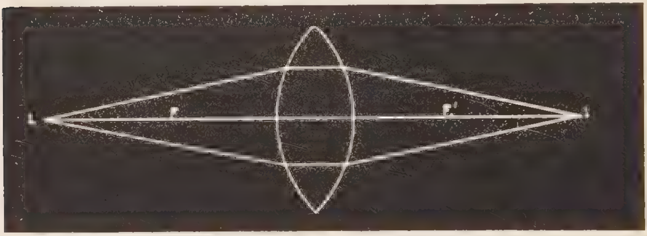


FIG. 6.

Divergent rays from a point L (Fig. 6) beyond the principal focus F meet at a point l beyond the principal focus F′ on the other side of the lens. If the point L is twice the focal distance of the lens, then l will be at the

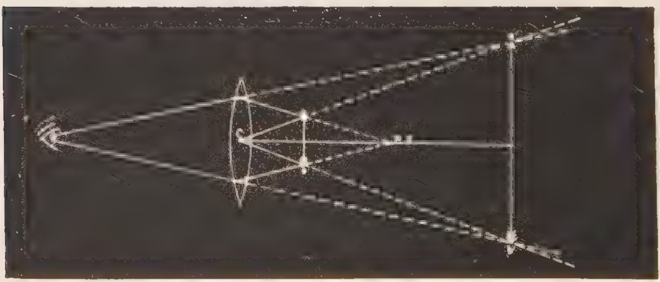


FIG. 7.

same distance on the other side. These two points are called conjugate foci, and are interchangeable—that is, the object may be at L or l, and the image is respectively at l or L.

If a luminous point be between the convex lens and the principal focus, the rays will still be divergent when they leave the lens on the opposite side, and consequently no real image is formed; but a magnified virtual image is formed beyond the principal focus on the same side,

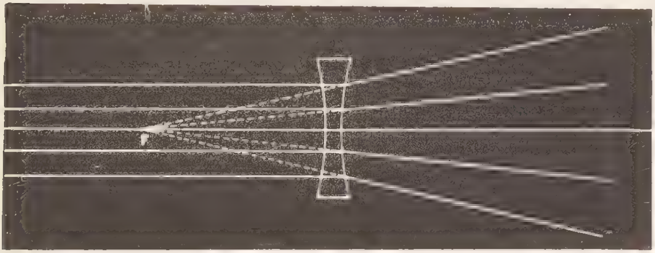


FIG. 8.

at a point called the virtual focus, and this virtual image is seen by an observer on the opposite side of the lens, the light from the points *a* and *b* appearing to the observer to come from *a′* and *b′* (Fig. 7).

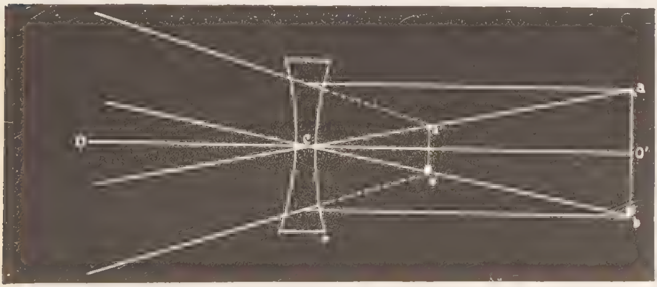


FIG. 9.

Concave Lenses.—Parallel rays passing through a concave lens diverge, and consequently never come to a focus; but these divergent rays, if prolonged backwards, will meet at a point F (Fig. 8).

This point is the (virtual) principal focus of a concave lens.

If an object be placed beyond the principal focus of a concave lens, an observer on the opposite side of the lens will see a virtual, erect, smaller image on the same side as the object; thus, rays from *a* and *b* will appear to come from *a′* and *b′*, and the object *a b* is seen as *a′ b′* (Fig. 9). As concave lenses have a negative focal distance they are denoted by the minus sign: −.

Cylinders.—Besides these spherical lenses there are cylindrical lenses—that is, lenses cut out of a cylinder;

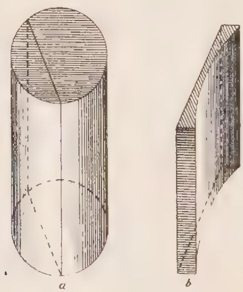


FIG. 10.

convex cylinders are cut from a solid cylinder (Fig. 10, *a*), concave cylinders from a hollow cylinder (Fig. 10, *b*), and may be regarded as the mould of convex cylinders. Cylinders have the property of not refracting any rays that pass along their axis, but rays passing at right angles to the axis undergo the maximum refraction corresponding to the strength of the lens, and so, according to the angle at which the rays impinge upon the lens, they undergo more or less refraction, as they are further away from, or nearer to, the axis of the cylinder; hence, a cylinder has no one focal point, but a line of foci parallel to its axis.

Cylindrical lenses are employed to correct regular astigmatism.

The axis of a cylindrical test lens is marked by a small line cut with a diamond in the glass, or by making the sides of the lens, parallel to the axis, opaque.

Numeration of Lenses. — The lens whose focal distance is 1 metre is taken as a unit, and its refractive power is called one Dioptry or Dioptre ("*D*"). A lens of twice the power of this—viz., 2 D—has a focal distance of $\frac{100}{2}$; *i.e.*, 50 cms.; a lens of half the power —viz., .5 D—has a focal length of 2 metres, and so on. The focal distance of a lens nD $= \frac{100 \text{ cms.}}{n}$

Under the old system, a lens whose focal distance was 1 inch was taken as the unit, and a lens whose focal length was 10 inches was called $\frac{1}{10}$, 30 inches $\frac{1}{30}$, and so on. The great disadvantage of this method of numeration was the inability to make it international, because the inch is not an international measure.

To convert the old numeration into the new, divide the denominator into 40; thus, lens $\frac{1}{5}$ is $\frac{40}{5} = 8$ D, and *vice versâ*, to convert dioptres into inches, divide the dioptre into 40, and the result is the focal length in inches; thus, 4 D $= \frac{40}{4} = 10$ inches focal length expressed as $\frac{1}{10}$ (see Appendix).

Testing Lenses.—It is important to be able to test a lens and find out its optical value. Instead of going through the process of finding its principal focus and measuring the distance of this from the lens centre, we place in front of it lenses of the opposite value; thus, if we wish to find the strength of a convex glass, we neutralize it with concave glasses.

A finer test is to employ the parallactic movement. If we look at a distant object through a convex glass and move the glass, the object appears to move in the opposite direction; if we use a concave glass, the object

appears to move in the same direction. So long as there is any movement we must place up concave or convex glasses, according as the displacement of the object is "against" or "with."

In testing cylinders we have to ascertain not only the value, but also the direction of the axis.

When cylinders are moved in front of the eye in the direction of the axis, objects looked at through them are *not* displaced; but the smallest rotation of the cylinder causes displacement, which reaches its maximum when the movement of the cylinder is in the direction opposite to its axis. In this position neutralize with cylindrical lenses of the opposite value, bearing in mind that displacement takes place "against" the movement so long as a convex lens predominates, and "with" the movement so long as a concave one predominates. The axes of the two lenses must coincide.

When testing a sphero-cylindrical glass the spherical lens should be first neutralized.

A great saving of time is effected by testing glasses with the *Geneva lens measure* and the *Maddox cylinder-axis finder.*

The Combination of Lenses—*Convex Spherical Lenses.*—The ordinary way for such lenses to be ground is to work half the power needed on each surface; thus, when + 4* is required, each surface of the lens is made equal to + 2, as if two plano-convex glasses of + 2 had their plane surfaces cemented together.

Another method of working a convex lens is to grind the surface away from the eye as a convex lens of higher power than is required, and the other surface concave of such a strength as to reduce the convex surface to the desired amount. Thus, when + 4 is ordered, one surface can be made + 7 and the other surface − 3, or one surface can be + 6 and the other − 2. Such lenses are

* In the following pages, the numeration of lenses will always be in dioptres, and "D" after the numeral will be generally omitted.

called *periscopic*, and have the advantage of enlarging the field of distinct vision ; the eye in all its movements is more or less at the same distance from the surface of the glass.

Concave Spherical Lenses.—These are usually made with half the strength required, on each surface. A certain amount of periscopic effect may be obtained by grinding the surface nearer the eye more concave and reducing the other : thus, – 8 may be, and usually is, made – 4 on each surface, or the surface nearer the eye may be made – 6 and the other – 2.

Cylindrical Lenses.—When a cylinder only is prescribed, it is ground on one surface, and the other is plane. When combined with a spherical lens it is usual to grind the spheric on one surface, and the cylinder on the other. When a convex sphere and cylinder are required, the periscopic effect can be produced by grinding a concave cylinder on the surface nearer the eye, and increasing the spherical strength by the amount of the cylinder. Thus, supposing + 2 cyl. axis vert. $\bigcirc$ + 3 sph. is needed, it may be ordered thus :

– 2 cyl. axis horizontal $\bigcirc$ + 5 sph.

In ordering glasses for mixed astigmatism (see page 129) the periscopic effect is produced by combining a convex cylinder with a concave sphere and mounting the latter next the eye.

As it is very important to divide the strength of the lens between the two surfaces when dealing with high powers, a cylinder if also required in such a case, must be worked on one of the spherical surfaces. These lenses are called *Toric* lenses, and any combination of spherical lens (.25 to 18), with cylindrical lens (from .25 to 3) can be supplied. Thus, if – 14 sph. $\bigcirc$ – 2 cyl. axis horizontal is required, one surface is made – 7 and the other – 7 sph. $\bigcirc$ – 2 cyl. These Toric lenses are very useful in high myopia, and also in aphakia.

Spherical Aberration.—In most lenses the rays passing through the peripheral part of the lens do not focus at the same spot as those which pass through the central portion. In convex lenses, when the peripheral rays focus in front of the central rays the *aberration* is spoken of as *positive*, and when the peripheral rays focus behind the central as *negative*. The crystalline lens suffers from spherical aberration, which is more or less hidden by the contraction of the pupil; but during mydriasis it may cause confusion of vision, which can be corrected by using a *pin-hole disc* in the trial frame, and thus cutting off the peripheral rays.

CHAPTER II.

OPTICAL PROPERTIES OF THE NORMAL EYE.

The eye is constructed in the form of a photographic camera. As in the camera, there is a closed darkened box open in front where there is an arrangement of lenses to focus an object on the back, at which spot there is the apparatus for receiving the perfectly formed image: the plate in the camera, the retina in the eye.

As in the camera, there are two conditions which must exist in the eye: firstly, the media must be transparent; and, secondly, the focussing must be so arranged that a perfect image of the external object lies on the retina—*i.e.*, the principal focus of the eye must coincide with the retina.

All deviations from this latter rule are called errors of refraction and accommodation.

The Refraction of the Normal Eye at Rest—i.e., in the Absence of any Effort of the Accommodation— *Dioptric Apparatus of the Eye.*—The simplest form of a dioptric apparatus is with two media of different refractive power, separated by a spherical surface.

Such a system is represented by Fig. 11., where $x\ y\ z$ is a spherical surface separating a less refractive medium on the left from a more refractive medium on the right. The line O A passing perpendicularly to the surface of the sphere and through its centre at N is called the optic axis.

All rays passing normally to the surface, such as R N

and S N like the optic axis, pass through N, and undergo no refraction; N, the centre of the sphere, is called the nodal point.

The point *y* where the optic axis cuts the sphere, is called the principal point.

Rays *c d*, parallel to the optic axis in the less dense medium, unite somewhere on the optic axis at the point F, called the posterior principal focus.

On the optic axis, in the less dense medium, there is another point (F′), called the anterior principal focus, whence divergent rays passing into the denser medium

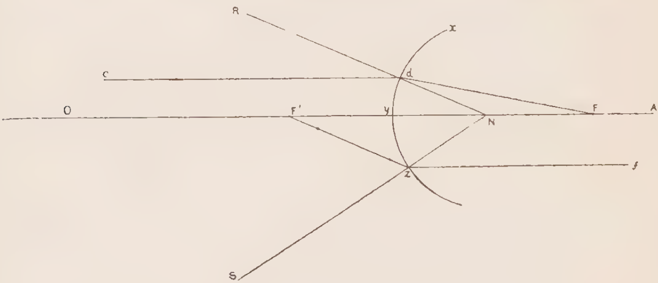


FIG. 11.

are refracted, and become parallel to the optic axis as at *zf*.

These four points—the principal point, nodal point, and anterior and posterior focus—are called cardinal points of the system.

In the eye the system is much more complicated. A ray of light passing into the eye meets the following surfaces and media in the order named: Anterior surface of the cornea, substance of the cornea, posterior surface of the cornea, aqueous, anterior surface of the lens, substance of the lens, posterior surface of the lens and vitreous. Thus there are four surfaces and, if we include the air, four media. As the anterior and posterior

surfaces of the cornea are parallel, we may neglect the substance of the cornea, and consider the two surfaces as one. Again, the aqueous and vitreous are so alike that we may assume them to be one medium. In this manner the eye is reduced to three surfaces and three media.

These three surfaces—the cornea, and the anterior and posterior surfaces of the lens—are symmetrically centred round the optic axis of the whole system, which may now be reduced to a compound system, consisting of the cornea and a bi-convex lens; we find the principal points p' p'' (Fig. 12) and the nodal points n' n'' of the cornea

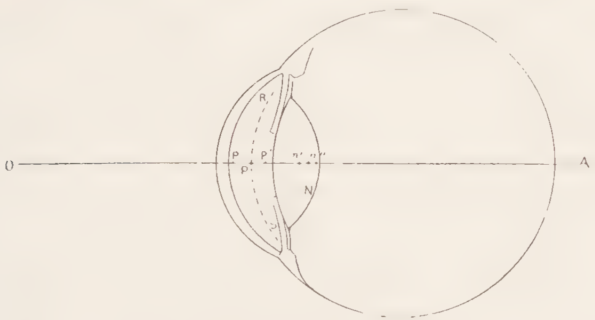


FIG. 12.

and lens; and, finally, take the mean of these two points, and get P the principal focus and N the nodal point of the "reduced eye," as suggested by Listing.

The positions of the cardinal points of the reduced eye are:

Principal point, in the aqueous, 2.3448 mm. behind the anterior surface of the cornea.

Nodal point, in the lens, .4764 mm. from its posterior surface and about 15 mm. from the retina.

Posterior principal focus, 22.819 mm. behind the anterior surface of the cornea—*i.e.*, on the retina of the normal eye. (This is the length of the standard eye.)

Anterior principal focus, 12.8 mm. in front of the anterior surface of the cornea.

The principal plane R P S (Fig. 13) is where the one surface of this reduced system passes through the principal point P which is considered the centre of refraction of the eye.

The optic axis (O A) is an imaginary line passing through the centre of the cornea and the nodal point, and meeting the retina a little above and to the nasal side of the fovea.

The nodal point corresponds to the optical centre, and, as we have already seen, all rays passing through it are unrefracted.

We can now ascertain how an image is formed on the retina.

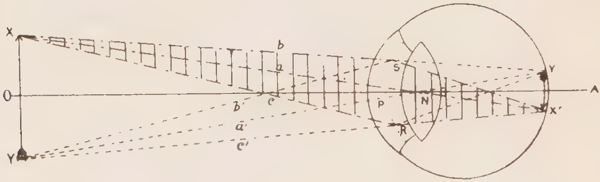


FIG. 13.

Let X Y (Fig. 13) be an object in front of the eye; each point of this sends out a pencil of divergent rays, and all those which pass into the eye, by the dioptric system, are made to converge again into a point on the retina.

Each such pencil of rays from the point X has a principal ray X*a*, which is normal to the surface, and, passing straight through the nodal point N without refraction, impinges on the retina at X′. The other rays from X are increasingly divergent, and are represented by X*b*, X*c*; they undergo refraction, and converge together at some point on the principal ray, which in the normal eye will be at X′. In like manner we can trace the rays from the other extreme point Y, which forms an image at Y′, and so for all the other points.

It will then be seen that we can, in tracing the formation of an image on the retina, ignore all the rays from a point of the object except the principal ray, which we trace through the nodal point, and by tracing all the luminous points from an object through the nodal point, we obtain in the normal eye an inverted image of the object on the retina.

The nearer the object is to the eye the larger will be its image, and *vice versâ*. **The size of the retinal image** is therefore directly proportional to the distance of the object from the eye.

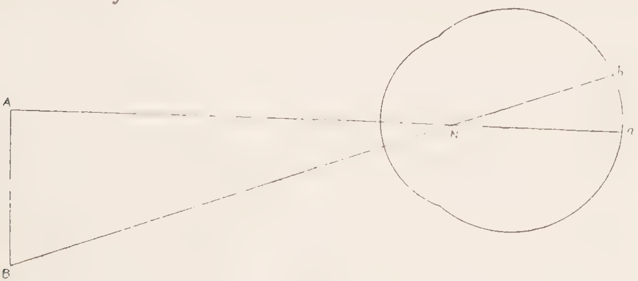


FIG. 14.

It is sometimes important for the oculist to determine the size of the retinal image of an object in order to discover the size of a diseased area, and if the size of the object and its distance from the eye be known, we can do this.

The triangles A N B and a N b (Fig. 14) are similar, hence $a\ b$: A B : : a N : A N—that is, the size of the area on the retina is to the size of the object as the distance from the nodal point to the retina is to the distance of the nodal point from the object. Let the latter be 10 metres and the size of the object 1 metre; we know that the distance a N is 15 mm., consequently:

$$a\ b : 1{,}000 :: 15 : 10{,}000$$

$$\therefore a\ b = \frac{15{,}000}{10{,}000} = 1.5 \text{ mm.}$$

The perfect type of eye is that in which the retina coincides with the posterior principal focus, and is called

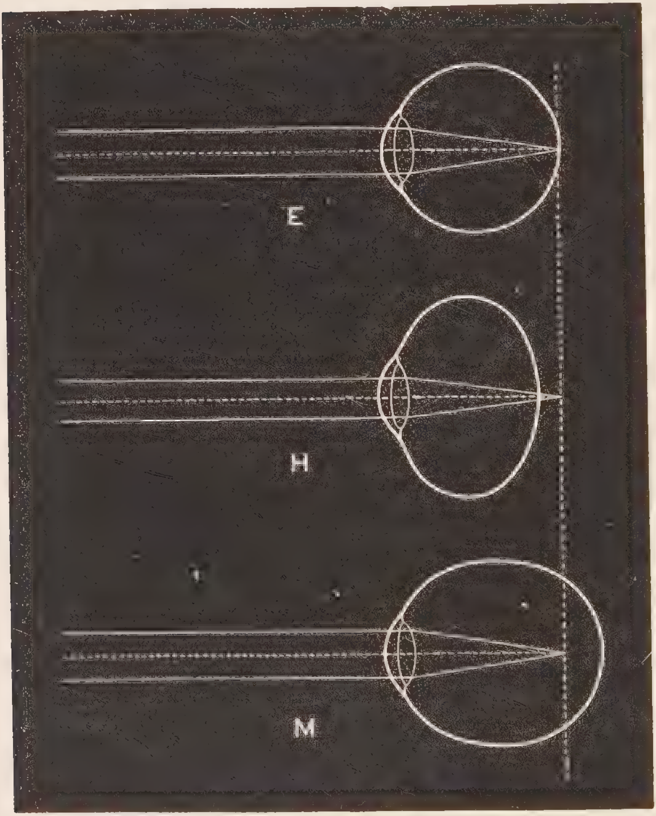


FIG. 15.

Showing parallel rays focussed on the retina in emmetropia (E), behind the retina in hyperopia (H), and in front of the retina in myopia (M).

the Emmetropic eye (E, Fig. 15), and any deviation from this is called **Ametropia**.

If the posterior principal focus is beyond the retina, the eye is too short, and parallel rays, when they meet the retina, have not yet come to a focus, and only convergent rays come to a focus. This is called Hyperopia (H, Fig. 15).

If the principal focus is in front of the retina, the eye is too long, parallel rays focus in front of the retina and only divergent rays focus on the retina. This condition is called Myopia (M, Fig. 15).

The Visual Angle and Visual Acuity.—Rays of light, proceeding from the two extremes of an object into the eye, meet at the nodal point N (Fig. 16) before crossing and forming the inverted image on the retina,

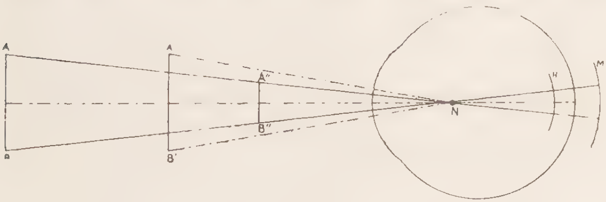


FIG. 16.

and the angle included at N is called the visual angle. A N B is the visual angle of the object A B (Fig. 16).

The size of the visual angle depends on the size of the object and its distance from the eye; thus A′ B′, which is the same size as A B, subtends a larger angle, and the image is larger; and again, A″ B″ subtending the same visual angle as A B would appear to be the same size, whereas it is much smaller. Fortunately, we do not gain our estimation of the size of objects by the visual angle alone; experience and comparisons with other known sizes are brought into play, and enable us to correct any erroneous judgment.

The smallest visual angle in which the standard eye can recognise an object, is an angle of one minute, so that

two points of light, such as two stars separated by an angular interval of less than one minute, would appear on the retina as only one point.

Test Types.—It is most important to have a standard measure for acuteness of vision, and Snellen has arranged test types on such a plan that each letter is made up of several parts, each of such a size that it subtends an angle of one minute vertically and horizontally, the whole letter subtending an angle of five minutes vertically and horizontally when read at the standard distance.

Thus, in Fig. 17, the F is made out of twenty-five squares, each subtending an angle of one minute when read by the normal eye at 12 metres; and the L, which

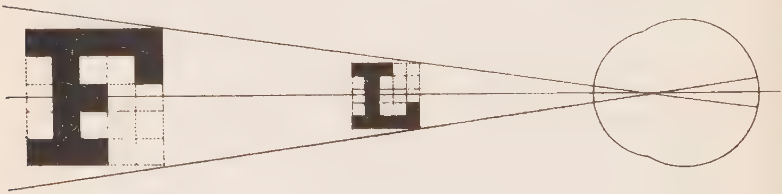


FIG. 17.

is constructed on the same plan, subtends the same angle when read by the normal eye at 6 metres.

The numbers over the different-sized letters represent the distance in metres at which the standard eye can read them; in other words, at that distance they subtend an angle of five minutes. For instance, the largest type, D = 60 (see type at end of book), can be read by the normal eye at 60 metres, and it subtends the same angle as the type D = 24 read at 24 metres and D = 6 read at 6 metres. The acuteness of vision is represented by a fraction which has for its numerator the distance in metres at which the type is read, and for its denominator the distance at which it ought to be read. The line D = 6 means that this type can be read by the normal eye at 6 metres,

and if the patient under examination can read it at 6 metres, the fraction is $\frac{6}{6}$—that is, normal vision. If the patient cannot see a smaller type than D = 12 at 6 metres, his vision = $\frac{6}{12}$; if D = 60 is the only letter that can be read at 6 metres, his vision = $\frac{6}{60}$—*i.e.*, one-tenth of the normal. If D = 60 cannot be read at 6 metres, the patient must be made to approach the type ; if he can just read this letter at 2 metres, his vision is $\frac{2}{60}$; he has only one-thirtieth of normal vision. Although $\frac{6}{6}$ is the standard of normal acuteness of vision, many eyes can see better —viz., $\frac{6}{5}$, or even $\frac{6}{4}$—*i.e.*, such eyes can read at 6 metres type that the standard eye cannot read at a greater distance than 5 and 4 metres respectively.

If the visual acuity is so lowered that the patient cannot see any letter at any distance, we measure it by finding whether he can count fingers, and if so, at what distance, and failing this, by finding whether he can distinguish between black and white. If vision is even worse than this, we take him to the light and pass the hand in front of the eye—*i.e.*, between the eye and the light ; if movement is recognised, we find out whether he can distinguish the *direction* of the movement.

Finally, if he fails at all these tests we take him into the dark room, and direct a strong beam of light on to the eye ; if this is not perceived, vision = 0 ; if it is perceived, we ascertain whether he has good projection, by reflecting the light on to the eye from different positions, and ascertaining whether he can tell whence the light is coming.

Type for Near Vision.—As the "schrift-scalen" of Professor Jaeger represent no standard, this type has been superseded by Snellen's, which is on the same principle as his distant type, the figure over the type signifying the greatest distance at which the normal eye can read it, and, of course, subtending an angle of five minutes at that distance. The sizes range from D = .5 to D = 4 (see type at end of book).

CHAPTER III.

ASTHENOPIA.

ASTHENOPIA, or eyestrain, is a symptom or group of symptoms the result of straining some part of the eye apparatus. It has been defined as *weak sight*. This is wrong, as weakness is no more a necessary feature than it is in any other form of fatigue. Tired sight it may be called, but *not* weak sight.

The Varieties of Eyestrain.—Eyestrain arises from strain of one or more of three distinct parts of the eye—

(i.) Ciliary strain, commonly called accommodative asthenopia, due to strain of the ciliary muscle.

(ii.) Muscular asthenopia, due to strain of the extrinsic muscles of the eye. Strain of the internal recti, or *convergence strain*, is the commonest form.

(iii.) Retinal asthenopia, due to strain of the retina and its connections.

Symptoms.—The symptoms are most varied, and may appear singly or associated—

(i.) *Obscurations*, usually present in hyperopia and presbyopia, and due to relaxation of the strained ciliary muscle.

(ii.) *Pain*—

(*a*) *Ocular*.—This may be only a feeling of tension or fulness in the eyes, but may become real pain of a dull, aching character, and the eyeballs may be very tender to pressure.

(*b*) *Neuralgia.*—Supra-orbital neuralgia, or "brow ague," a superficial pain in the region of distribution of the first division of the fifth nerve.

(*c*) *Headache.*—This is by far the commonest symptom.

Ocular Headache.—Ocular headache varies both in its position and character. It may simply amount to a slight aching over the eyes or at the back of the orbit; it may be a frontal headache. Sometimes it originates and remains limited as a vertical or occipital headache, or the pain may originate in the brows and pass to the vertex and occiput, and even down the spine. It may be unilateral, a typical hemicrania, and may be indistinguishable from a true migraine.

It is impossible to lay down any rule as to the position of ocular headache: *the position varies with the individual.* Some people with a headache, whatever the cause, describe it as frontal, others as vertical, and so on. The character also varies with the individual. In some people headache is generally superficial, akin to a neuralgia; others feel it to be deeply seated. It may be a dull, heavy ache, difficult to localize accurately, or it may be a sharp, shooting, lancinating pain that seems to start from some tender spot in the scalp or forehead. Some describe the pain as an opening and shutting of the skull, or as if a nail were being driven into the vertex. The commonest form of asthenopic headache is a dull pain over one or both brows.

It is important to remember that the headache of eyestrain is very often *periodic.* It does not follow that when the headache occurs it necessarily implies the presence of greater eye fatigue; the amount of strain may be the same as when no headache occurred, but the *individual* is in a different condition. Catamenial headache is very often due to eyestrain.

The immediate antecedent of an attack of migraine, a "nerve storm," is a condition of unstable equilibrium and gradually accumulating tension in the parts of the nervous system more immediately concerned, while the paroxysm itself may be likened to a *storm*, by which this condition is dispersed, and equilibrium for the time restored (Liveing). It is thus possible that eyestrain may be just the impetus required to start one of the attacks—in other words, among the different exciting causes in different cases of migraine, eyestrain may rank as one. Most writers agree that the age for migraine is between puberty and thirty, which is the period during which asthenopia is very common. But there is no doubt that many cases which have been considered a true migraine were in reality cases of asthenopia.

(iii.) *Vertigo and Sickness.*—Diplopia is the chief cause of these symptoms, and consequently it is mostly found in muscular asthenopia. If the internal recti are subjected to excessive strain, they break down from stress of work, and relax suddenly or gradually, and their opponents, the external recti, which have been in a passive state of tension, actively contract and pull over the eyes, causing diplopia.

Very often this diplopia is only temporary, for the very good reason that the cause is removed by the patient. In convergence "insufficiency," if the work is too near, the effort of the internal recti to preserve binocular vision is so great that the muscles refuse to work at such high pressure any longer; the result is diplopia, with the inevitable necessity on the part of the patient to suspend work. Sometimes the lesser symptoms, pain and headache, cause the patient to cease work before diplopia arises.

The double vision causes a "retinal confusion"; this confusion produces on the individual a sense of want of equilibrium, causing vertigo and, if prolonged, nausea, vomiting, dyspepsia, palpitation, and dyspnœa.

Vertigo is probably in all cases a *motor phenomenon*, and although in many cases of ocular vertigo the symptoms appear to be caused by "retinal confusion," this very confusion causes a sense of instability. In diplopia, the non-correspondence of the retinal images, and the false projection, produce a "confusion," and this confusion produces a sense of "want of equilibrium."

(iv.) *Insomnia*.—Insomnia is a complaint that may be elicited from many patients who are the subjects of severe asthenopia. The hyperæmia of the brain, the headaches, and the general low tone of the nervous system easily explain the symptom.

(v.) *Inflammation*.—Although at first there are no signs of inflammation or congestion in the eyes, if the eyestrain remains unrelieved they may appear, and we observe all the symptoms of conjunctivitis; the patient suffers from red, irritable, and watery eyes, and the papillæ hypertrophy, producing "granular lids," a condition which reacts upon and increases the irritability of the eyes. Blepharitis and other troubles may follow, and the optic disc has been seen congested and even swollen.

Blepharitis is a very common symptom of eyestrain in children.

Finally, eyestrain predisposes eyes to diseases which might otherwise not appear. Amongst the commonest of these I may mention phlyctenulæ, conjunctivitis, corneal ulcers, glaucoma, and cataract.

The Relation between Eyestrain and Severe Neuroses.—At the present day the universal recognition of asthenopia as the cause of many troubles that formerly were not supposed to be in any way connected with it, has led, as one might expect, to the "pendulum swinging" too much the other way. We have no proof that such diseases as epilepsy and chorea owe their existence to eyestrain; but eyestrain, like any other peripheral irritation, may start an attack in an epileptic or choreic patient, and if

the peripheral irritation, in this case the eyestrain, is removed, the attacks may become fewer and less severe, or even disappear altogether (see p. 198).

The symptoms of eyestrain are *nervous* phenomena, naturally most prone to make their appearance in a *nervous* age or in *nervous* people, and dependent upon either an abnormal use of, or an abnormal condition of, the eyes.

Differential Diagnosis of Asthenopia.—Mistakes have often been made in assigning some serious disease, such as brain mischief, as the cause of the symptoms of asthenopia.

It is most important to thoroughly test the eyes of those who complain of headaches or any other asthenopic symptom, and if this were done at first instead of at last, as is so often the case, a large amount of disappointment to the medical man and the patient would be avoided. It is important to remember that the headache of brain tumours is independent of any visual effort, and that optic neuritis is to be looked for as a very probable association. Frontal or temporal pain, which may be more of the character of a neuralgia, is often caused by a decayed tooth. It is possible that eyestrain may also exist, and we then have the two reflex causes acting together, the one increasing the effect of the other. Hence in all cases where correction of the ocular defect does not yield a satisfactory result, we should have the teeth overhauled by an experienced dentist. Indeed, every possible peripheral irritation should be eliminated.

The causes and treatment of asthenopia will be dealt with in the following pages.

CHAPTER IV.

ACCOMMODATION.

WHEN with one eye closed, the other eye focusses a needle a metre from the eye, another needle placed half a metre from the eye will appear blurred.

If A (Fig. 18) be the first needle, a clear image is formed by the exact focussing of it on the retina at A′, while the image of B will be focussed beyond the retina at B′, the rays from B impinging on the retina in the form of a collection of diffusion circles.

On the other hand, if the needle B be focussed on the

FIG. 18.

retina—*i.e.*, if its image be clearly seen—the needle A will appear hazy or out of focus, because its image is focussed in front of the retina, and, after crossing, the rays impinge on the retina as diffusion circles.

Diffusion Circles. — Two points of light, if near one another and out of focus, appear as two diffusion circles, overlapping each other if near enough (Fig. 19, A).

As a line in focus may be considered to be an infinite number of points of light in focus, so a line out of focus

consists of a series of overlapping diffusion circles (Fig. 19, B) which makes the line appear as a broad band, as Fig. 19, C. The further the rays focus from the retina, the larger will be the diffusion circles. In Fig. 20 both A and B are "out of focus," but B is more so than A, and consequently the diffusion circles formed by B occupy a larger area; and again, the larger the pupil the larger the area of diffusion circles, because as the pupil contracts it cuts off the outside rays.

The alteration of the eye by its focussing mechanism is called **accommodation.** The photographer focusses by lengthening or shortening the distance between the back of the camera and the lens, but he could also focus

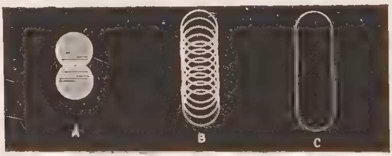


FIG. 19.

by adding a convex or concave lens to that he is already using.

It is in this latter way that the eye focusses; the eye cannot lengthen, but the lens can become more convex, which has the same result as adding a convex lens.

In the normal standard eye, parallel rays, coming from a distance beyond 6 metres, are focussed on the retina when the eye is at rest—*i.e.*, when the apparatus of accommodation is not being used; but when the eye wishes to see clearly any object nearer than 6 metres, the lens must become more convex.

After looking at the needle A, when we look at needle B and obtain a clear image, we are distinctly conscious of an effort, and the nearer we approach B to the eye

the greater the effort, till we reach a spot near the eye when no effort will produce a clear image, because the rays from the needle are too divergent to be focussed on the retina. The nearest point to the eye at which the object is recognised as a perfectly clear image is called the near point "P." After looking at the needle close to the eye, and again looking at the distant needle, we are conscious of a relaxation of our efforts.

How do we know that this focussing or accommodation is caused by an increased convexity of the lens?

The Mechanism of Accommodation.—If we take a patient into the dark room and hold a candle in front of the eye a little to one side, we shall see three images of this candle in the eye. One, the brightest, is upright,

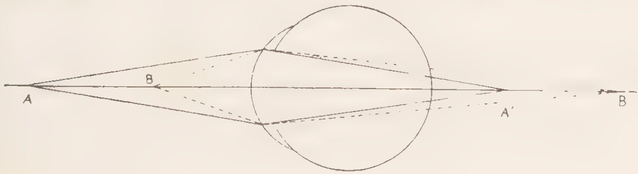


FIG. 20.

and the reflection comes from the anterior surface of the cornea; the second, duller, is also upright, and is the reflection from the anterior surface of the lens; and the third is inverted, duller, and smaller, and is from the posterior surface of the lens. We tell our patient to look into distance, and we note the size and position of these images, and then, carefully watching them, we tell him to gaze at a near point. We shall then see no change in the first image (proving the fallacy of the old theory that the cornea becomes more convex during accommodation), and little change in the third; but the middle image—viz., that from the anterior surface of the lens—becomes distinctly smaller and moves forward, showing that this surface has become more convex.

In accommodation, then, the lens becomes larger in its antero-posterior diameter, and as it does not alter in volume, it becomes narrower in its equatorial dimensions.

We will now inquire how this change is brought about.

According to Iwanoff, the ciliary muscle arises from a tendinous ring (T, Fig. 21) close to the insertion of the iris and Schlemm's canal (*c*S), at the posterior surface of the sclerotic, close to its junction with the cornea. The muscle then passes backwards, and may be divided into three parts: (1) the outermost part or meridional portion passing into the posterior tendon (*m*), to be inserted into the choroid; (2) the radiating portion (*r*); and (3) the annular portion or circular muscle of Müller (*c*) passing directly backwards and inwards respectively, to be inserted into an agglomeration of fibres called the zone of Zinn (*z*). These fibres arise partly from the ciliary portion of the retina at the ora serrata (o*s*) and partly from the ciliary processes and the intervals between them, and they pass forwards and backwards, to be inserted into the anterior and posterior capsule of the lens. When the ciliary muscle contracts, it pulls forwards and inwards the zone of Zinn, the inward pull being specially brought about by the contraction of the circular muscle of Müller. By the contraction of the longitudinal fibres, the choroid and the portion of the ciliary body near it are pulled forward.

The annular muscle of Müller is a sphincter, and does the principal work; hence it is always larger in hyperopia, because of the extra accommodation work necessary, and is badly developed in myopia. According to Helmholtz, strongly supported by Hess, the contraction of these muscles relaxes the zone of Zinn, which is compressing the lens. The lens is thus allowed, by virtue of its elastic fibres, to assume a more convex shape, producing the same effect on rays passing through it as if a convex glass were placed before the eye. This causes a greater

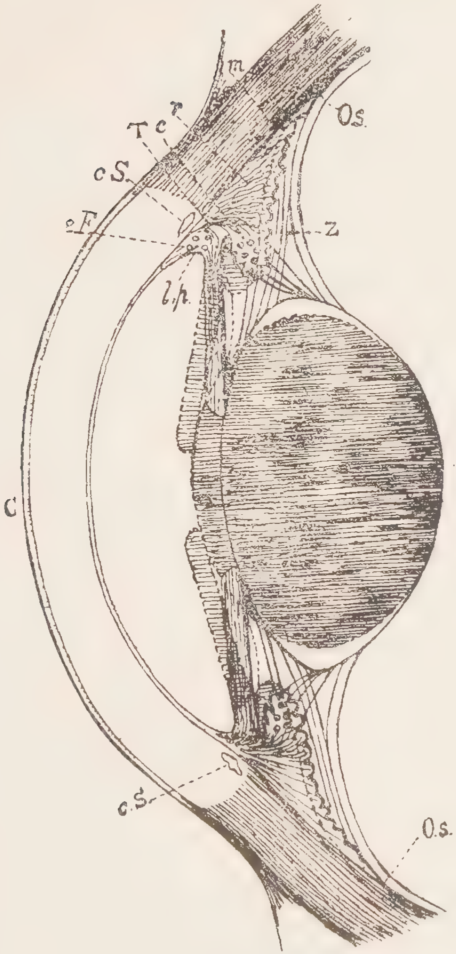


FIG. 21.—DIAGRAMMATIC SECTION OF THE CILIARY REGION OF THE EYE.

C, cornea; *c S*, Schlemm's canal; *O s*, ora serrata; *l p*, pectinated ligament; *e F*, Fontana's space; *T*, tendinous ring; *m*, meridional fibres; *r*, radiating fibres; *c*, circular fibres of the ciliary muscle; *Z*, zone of Zinn.

The full lines indicate the lens, iris, and ciliary body at rest, and the dotted lines the same in a state of accommodation. (Reduced from Landolt.)

convergence of rays passing into the eye, and enables an object which was previously focussed behind the retina to be focussed on it. When the ciliary muscle relaxes, the zone of Zinn again compresses the lens, which resumes its less convex shape.

In opposition to this theory Tscherning maintains that the action of the ciliary muscle is to *increase* the tension of the zonula, and to alter the lens from a spherical to a hyperboloid form, and he founds his theory on the work of Thomas Young. According to this theory the lens becomes more conical under accommodation, and the contraction of the pupil that occurs at the same time, masks the increased aberration which results from the flattening of its periphery.

The posterior surface of the lens does become slightly more convex during accommodation, but it does not change its position, the increase of thickness of the lens being effected by the advance of the anterior surface.

Amplitude of Accommodation.—At rest the eye is adapted for the most distant point it can see distinctly—viz., its *punctum remotum* (R), while the greatest possible contraction of the ciliary muscle adapts the eye to the nearest point it can see distinctly—viz., its *punctum proximum* (P), which represents the greatest possible contraction. The force required to change the eye from R to P is called the amplitude of accommodation, and is represented by the *difference* between the refraction of the eye at rest and the refraction when doing its utmost work. The equation is:

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$$

or

$$a = p - r$$

Where "a" equals the numbers of dioptres represented by the accommodation, "p" equals the number of dioptres represented by the eye when in a state of maximum refraction—*i.e.*, when adapted for its nearest distinct point—

and "r" equals the number of dioptres represented by the eye at rest—*i.e.*, when adapted for its furthest distinct point.

In *Emmetropia*, as R is at infinity "r" can be ignored.

$$\therefore a = p$$

Therefore the amplitude of accommodation is represented by the nearest distinct point; if this is 9 cms. off, "a" = $\frac{100}{9} = 11$—that is, the power of accommodation is equal to a lens of eleven dioptres.

In myopia "r" has a positive value. Take, for example, a person whose furthest distinct point with the eye at rest is 33 cms. (that is, a myope of 3), and suppose that his nearest distinct point is 7 cms., then

$$\begin{aligned} a &= p - r \\ &= \frac{100}{7} - \frac{100}{33} \\ &= 14 - 3 \\ &= 11 \end{aligned}$$

In other words, 14 would represent his amplitude of accommodation if he were emmetropic, but being myopic to the extent of 3, we must subtract that, which leaves us 11 to represent his amplitude.

In hyperopia, as we shall see later, "r" is negative; therefore the equation is:

$$\begin{aligned} a &= p - (-r) \\ &= p + r \end{aligned}$$

Thus, an eye hyperopic to the extent of 5, having its near point at 25 cms. from the eye, has an amplitude of accommodation equal to a lens of 9. To see 25 cms. off, the eye requires an accommodation of 4 ($\frac{100}{25}$), but it has already expended 5 for distance, so that

$$\begin{aligned} a &= p - (-r) \\ &= 4 - (-5) \\ &= 4 + 5 = 9 \end{aligned}$$

We thus see that to determine the amplitude or range of accommodation we must find R and P.

R is represented by the refraction of the eye at rest.

P we find as follows:

Take a tape graduated on one side in centimetres and on the other in corresponding dioptres; the zero-end of the tape is attached to the handle of a frame, into which may be introduced either a perforated diaphragm or a paper with fine print upon it, or threads or hairs; or the ordinary near vision test card and separate measure may be used. The test object is brought towards the eye under examination (the other one being covered) until it begins to appear indistinct, we then read off on the tape the distance of P from the eye, and the corresponding dioptres (p) representing the maximum refractive power of the eye.

If from any cause, such as presbyopia or high hyperopia, the patient's near point is so far that the above tests cannot be employed, we place in front of the eye such a convex glass as will bring the punctum proximum (P) closer, and enable him to read $D = .5$ or see the words in the frame, such glass to be, of course, deducted afterwards. Thus, supposing a person with $+2$ can bring the test object up to 25 cms. and no nearer, we read off on the other side of the tape 4, and we subtract the $+2$ from this, which gives us $p = 2$—that is, P is 50 cms. off if he is an emmetropic presbyope; this represents his amplitude of accommodation. If he is hyperopic to the extent of 6, then

$$\begin{aligned} a &= 2 + 6 \\ &= 8 \end{aligned}$$

Or suppose the patient, being hyperopic and presbyopic, requires $+5$ to read at 33 cms., if his hyperopia $= 6$, then

$$\begin{aligned} a &= p + r \\ &= (3 - 5) + 6 \\ &= 4 \end{aligned}$$

We can also find the amplitude of accommodation by ascertaining the strongest concave glass the patient can "overcome." In emmetropia such glass represents the amplitude of accommodation. In hyperopia the amount of hyperopia must be added, and in myopia the amount of myopia must be deducted.

As an example, we find a patient who is hyperopic to the extent of 2 can still read $\frac{6}{6}$ with -4, but he cannot do so with -5; thus his amplitude of accommodation is $4+2=6$.

The **Region of Accommodation** is quite different

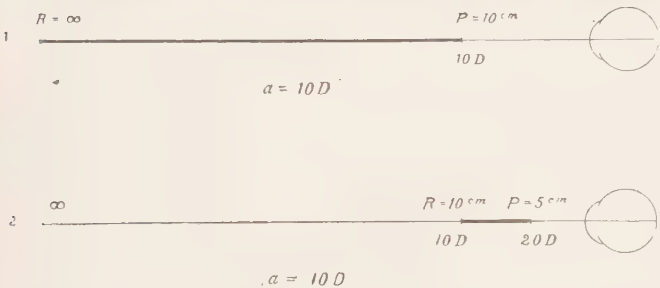


FIG. 22.

from the range, and gives very little idea of the work done.

Thus, the region of accommodation in an emmetropic eye as Fig. 22 (1), is from infinity (R) to 10 cms. (P) in front of the eye, while in Fig. 22 (2), a myopic eye, it is only from 10 cms. (R) to 5 cms. (P) in front of the eye, and yet in each case the same amount of accommodation work is done, which is equal to a lens of 10.

Accommodation is spoken of as absolute, binocular, and relative.

Absolute accommodation is the full amount of accommodation of one eye, the other being excluded.

Binocular accommodation is the full amount of accommodation which both eyes, converging, can exert together.

Relative accommodation is the limit within which accommodation may be increased or decreased, the convergence remaining the same (see Convergence, page 51).

CHAPTER V.

CONVERGENCE.

Anatomical and Physiological Considerations—The eyeball lies in the orbital socket, surrounded by Tenon's capsule, which is the thickened anterior layer of the cellular tissue of the orbit. The muscles which move the eye are six in number, and, with the exception of the inferior oblique, which arises from the anterior and inner part of the floor of the orbit, they all arise from the apex of the orbit. These muscles may be considered as three pairs, each pair rotating the eye round a particular axis. The four recti—viz., superior, inferior, internal, and external—pass forwards, pierce Tenon's capsule, from which they receive a sheath, become tendinous, and are inserted into the sclerotic not far from the margin of the cornea, the most anterior insertion being that of the internal rectus, which is about 6 mm. from the margin of the cornea. The superior oblique passes forwards to the upper and inner angle of the orbit, where it becomes temporarily tendinous, and passes through a pulley, after which it becomes muscular again, and changes its direction, passing backwards and outwards through Tenon's capsule to be inserted (tendinously) into the sclerotic, at the back and upper part of the eye. The inferior oblique passes outwards and backwards, underneath the inferior rectus, and then between the external rectus and the eye, to be inserted into the outer, posterior, and lower part of the eyeball, not very far from the entrance of the optic nerve.

The axis of rotation of the internal and external recti is vertical, and that of the superior and inferior recti, horizontal, with the inner extremity more forward than the outer (Fig. 23). That of the oblique muscles lies also in the horizontal plane, with its anterior extremity tilted outwards.

The movement of looking—

1. Upwards is produced by			... ...	Superior rectus. Inferior oblique.
2. Downwards	,,	,,	... ...	Inferior rectus. Superior oblique.
3. Outwards	,,	,,	... ...	External rectus.
4. Inwards	,,	,,	... ...	Internal rectus.

When both eyes look to the right, we have contraction of the right external and left internal recti, and when they look to left, contraction of the left external and right internal recti.

Movement of the eyes up and in is produced by 1 and 4—viz., superior rectus, inferior oblique, and internal rectus movement down and out by 2 and 3, and so on.

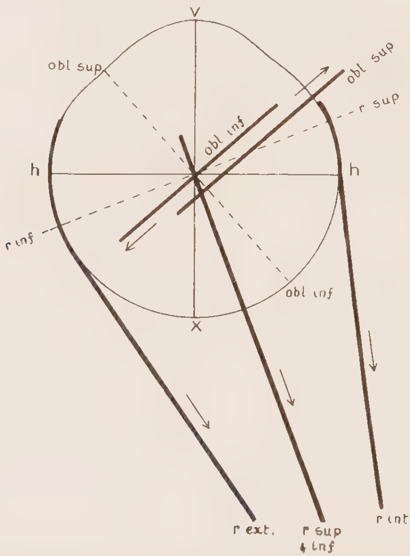


FIG. 23.—DIAGRAM OF THE ATTACHMENTS OF THE MUSCLES OF THE LEFT EYE AND OF THEIR AXES OF ROTATION (MICHAEL FOSTER).

The attachments of the muscles is shown by the beginning of the thick lines, and the direction of the pull is shown by the arrows. V X represents the visual axis, and h h a line at right angles to it.

The axis of rotation of the internal and external recti, being perpendicular to the plane of the paper, is not represented; that of the other muscles is indicated by the broken lines.

The external rectus is supplied by the sixth nerve, the superior oblique by the fourth, and the others by the third.

Convergence of the eyes is produced by the associated movements of both the internal recti. The nuclei (*r r′* Fig. 24) of that part of

the third nerve which supplies these muscles may be connected by fibres (c''), illustrating the principle that there is bilateral association of the nerve nuclei of muscles bilaterally associated in their action (Broadbent). This explains the convergence of a covered eye. A. Graefe says that one of the factors causing the covered

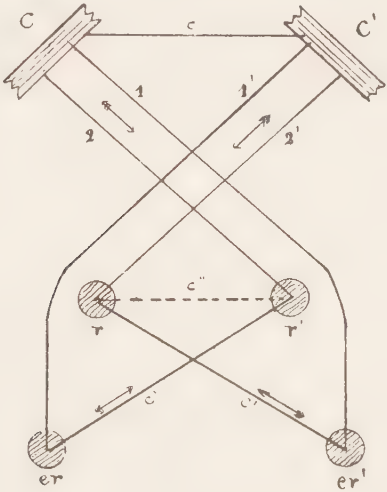


FIG. 24. (AFTER ROSS.)

CC′, Cortex of right and left cerebral hemispheres; 1, 2, Fibres of the pyramidal tract uniting C, the cortex of the right hemisphere, and r′ and er′, the nuclei of the *left* internal and external rectus; 1′, 2′, Fibres of the pyramidal tract connecting the cortex of the left hemisphere with r and er, the nuclei of the *right* internal and external rectus muscles; c, Fibres of the corpus callosum uniting identical regions of the two hemispheres; c′, Commissural fibres connecting the spinal nucleus of the internal rectus of one eye with that of the external rectus of the opposite eye; c″, Suggested commissural fibres connecting the nuclei of the two internal recti.

eye to converge is a "Convergenzgefühl," or, as Hansen Grut expresses it, a "Nahebewusstsein" a consciousness of nearness. Landolt denies this, and asserts that the excluded eye fixes correctly through the connection between accommodation and convergence alone.

It is important to remember that when a stimulus passes primarily to the nucleus of the internal rectus, it is associated with the same muscle of the opposite side, and convergence takes place; whereas the conjugate movements of the eyes to the right or left are produced by stimuli passing *primarily* to the nucleus of the *external* rectus, which nucleus is connected with the nucleus of the internal rectus of the opposite side (Fig. 24). We may have both these stimuli occurring at the same time—viz., primary stimulus to the internal recti to converge, and to the external rectus of one side associated with the internal rectus of the other side—to produce lateral movements of the eyes.

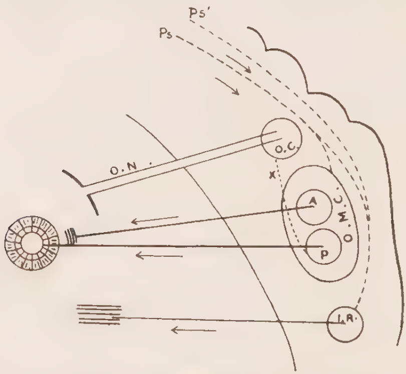


FIG. 25.—SCHEME SHOWING THE OCULO-MOTOR CENTRE AND SOME OF ITS CONNECTIONS (ADAPTED FROM ERB).

PS, Psychical impression (the wish to accommodate being the stimulus); PS', Psychical impression for voluntary converging strabismus; A, Accommodation centre with motor nerve to ciliary muscle, and P, Centre for the sphincter of the iris with motor nerve, the two forming the oculo-motor centre, O.M.C.; I.R., Internal rectus centre, with motor nerve to internal rectus muscle; O.N., Optic nerve from retina to O.C., Optic centre, and connected with P, the pupillary centre; X, is the seat of the lesion causing reflex pupillary immobility.

The oculo-motor centre (Fig. 25, O.M.C.) is situated beneath the floor of the aqueduct of Silvius. It includes (1) the accommodation centre (A), lying most anteriorly near the middle line, and (2) the pupil constrictor centre (P). The nucleus of the internal rectus (I.R.) lies further back. Filaments pass along the third or oculomotor nerve from these centres to the ciliary muscle, the sphincter

of the iris and the internal rectus, and are so associated that contraction of the ciliary muscles for accommodation, of the pupils, and of the internal recti for convergence, are all three associated in their actions. One impulse—viz., a psychical impression, a wish to look at a near object—passes from the motor centre in the cortex of the brain to these nuclei, and the result of this one impulse is the united action of these different muscles; the action is not always simultaneous, for convergence often lags behind accommodation (see page 49).

Many people can voluntarily squint inwards, but they will be found to accommodate for a near point at the same time; some few can, however, do so without accommodating, and in such cases the psychical impression probably passes straight to the nucleus of the rectus internus by PS′ (Fig. 25).

Binocular Vision.—Man has binocular vision—that is, the image from an object falls upon the retina of each eye simultaneously, and in normal binocular vision on exactly the same region of the retina; for if the images did not overlap, two images would be seen, and so-called "double vision" would be the result. The absence of double vision does not necessarily imply the presence of normal binocular vision with fusion of the two images, for one eye may be blind or its image suppressed by the brain (monocular vision). Many people use one eye only, for years, without discovering the fault. The best and quickest test for determining whether binocular vision is present or not, is Snellen's apparatus, described on page 145.*

Whereas, then, in discussing accommodation we considered the eye simply as an optical apparatus, now we must consider the two eyes together as forming *one whole*, and on their proper associated movements must depend perfect binocular vision.

If binocular vision be impossible, through some great defect of the optical apparatus or the muscles, no attempt

* Any of the tests for latent deviation, mentioned later, may also be employed.

will be made to produce it, and no strain will follow. On the other hand, apparently normal binocular vision may exist; but to produce this, a demand in excess of the power is put upon a muscle or a set of muscles, and the result is strain, either producing or tending to produce the symptoms of muscular asthenopia.

The Relation of the Two Eyes to each other in Normal Distant Vision.—Michael Foster says that the *primary position* of the eyes is "that which is assumed when, with the head erect and vertical, we look straight forwards to the distant horizon; the visual axes of the two eyes are then parallel to each other and to the median plane"—that is, in ideal binocular *distant* vision, the eyes being at rest and all the muscles in equilibrium with respect to each other, *the visual axes are parallel.*

Test for Latent Deviation of the Eyes for Distance.—If a person with normal vision be directed to look at an object in the distance, and one eye be covered for twenty or thirty seconds, if there be any latent deviation it becomes (as a rule) manifest, and on uncovering the eye there will be diplopia for a brief space of time, the covered eye moving, in order to fuse the two images—in, if there be latent divergence, and out, if convergence. A more accurate method of conducting this test is to destroy the possibility of binocular vision—*i.e.*, fusion—by means of a prism, with its base up, placed before one eye, or, better still, by the apparatus suggested by Maddox, called the "glass rod test"; by which means we can not only at once detect concealed deviation, but can also measure the amount.

The Maddox Test.—A glass rod (Fig. 26, a) is arranged in a metal disc, which fits into the trial frame.*

* Fig. 26, b represents a simple form of this apparatus which can be made by uniting four or five glass rods with sealing-wax. This must be held before the eye, as it does not fit into a trial frame.

Maddox Distance Scale

Horizontal latent deviations — Vertical latent deviations

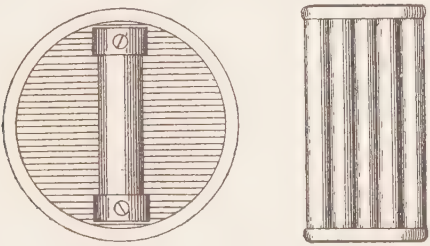
Orthophoria | Exophoria | Esophoria | Orthophoria | Left Hyperphoria | Right Hyperphoria

(In the above illustrations the glass rod is before the Right Eye)

Maddox Scale for $\frac{1}{4}$ Metre

To face page 42.

If this rod be placed before one eye, the other eye remaining uncovered, and a small flame be looked at from a distance of more than 4 metres, the eye in front of which the rod is placed sees the flame merely as a streak of light, and, the images of the two eyes being so dissimilar, there is no desire on the part of the brain to fuse them; consequently the two eyes assume their position of rest. If the rod be placed horizontally in front of the right eye, there is a vertical streak of light, and if this streak coincide with the image of the candle seen by the left eye, the visual axes are parallel (orthophoria); but if it do not, then when the streak is on the



a b

FIG. 26.

same side as the rod (in this case the right side) there is latent convergence (homonymous diplopia), when on the other side there is latent divergence (crossed diplopia). If a scale be used as suggested by Maddox (see plate) the number on the scale through which the streak of light passes records the amount of diplopia; or prisms may be put up in front of the other eye, or the rotary prism used (see page 212). The weakest prism that causes the two images to coincide, records the amount of diplopia. The Maddox distance scale is marked for 5 metres, and roughly every $3\frac{1}{2}^\circ$ represents a metre angle. To be quite exact, every $3^\circ\ 40'$ or 32 cms. is a metre

angle. If the scale be used at 4 metres, then every 25.5 cms. represents a metre angle.

If we wish to measure vertical deviations we turn the rod vertically, and thus obtain a horizontal streak of light. If this streak pass through the middle of the flame there is no vertical deviation, but if it be above or below there is hyperphoria of that eye which sees the lower image—*i.e.*, if the streak of light be lower there is a tendency to upward deviation (latent hyperphoria) of the eye in front of which the rod is placed.

Before this test is applied any refractive defect must be corrected. By making a large number of examinations by this method, we can easily prove the correctness of the statement, that, *for all practical purposes, the visual axes of the two eyes in normal binocular vision are parallel.* So much for what is called the static equilibrium of the ocular muscles. Now we proceed to examine the dynamic condition—that is, the relation of the muscles in binocular near vision; in other words, during *convergence.*

Convergence "is the direction that the eyes must give to their lines of fixation in order that they may be simultaneously directed toward the point of fixation." When both eyes are fixing an object 6 metres (or more) distant they are parallel, and C (which represents convergence) = 0; when the eyes simultaneously fix an object 1 metre off in the median line, both internal recti contract and the eyes converge; convergence is then said to be 1 metre angle, C = 1 m.a. This metre angle is the unit of convergence. If the eyes converge to a point 50 cms. off, then $C = \frac{100}{50} = 2$ m.a.; if 20 cms. off, $C = \frac{100}{20} = 5$ m.a.; and if the object be three metres off, $C = \frac{1}{3} = .33$ m.a. In Fig. 27 E E is the base line connecting the two eyes, and E R′ and E R′ are two lines at right angles to this base and therefore parallel. If the two eyes look at a point R, the angle R′ E R is the "metre

angle," or, better still, as R′ E R is equal to E R P, the latter may be called the "metre angle." To Nagel belongs the credit of devising this method of measuring the amount of convergence. The metre angle (or "meter-winkle," as he calls it) of convergence corresponds to the dioptre of accommodation. Thus, an emmetrope who is fixing binocularly a point 1 metre off, is using 1 dioptre of accommodation, and convergence is 1 m.a., and if the point be 25 cms. off, he is using 4 dioptres of accommodation, and his amount of convergence is $\frac{100}{25}$ = 4 metre angles.

Amplitude of Convergence.—The same formula is used as in estimating the amplitude of accommodation, viz.:

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$$

or expressing the equation in metre angles,

$$a = p - r$$

Where "a" represents the amplitude, "p" the maximum, and "r" the minimum, of convergence.

When R is at finite distance (Fig. 27), we have $a = p - r$, that is, the amplitude of convergence is the amount of convergence required to direct the visual axes of the two eyes simultaneously to the point P, starting from the binocular distant point R. When R is at infinity—that is, when the visual axes are parallel, "r" can be ignored, and the equation stands—

$$a = p$$

When the visual axes diverge, R is beyond infinity (R″), and the axes will, if prolonged backward, meet at a point $-$ R, which is negative; the equation will then be—

$$a = p - (-r) = p + r$$

To distinguish the equation from that used in accommodation it is common to prefix or affix a "c," thus:

$$ca = cp - cr,$$

or
$$a^c = p^c - r^c.$$

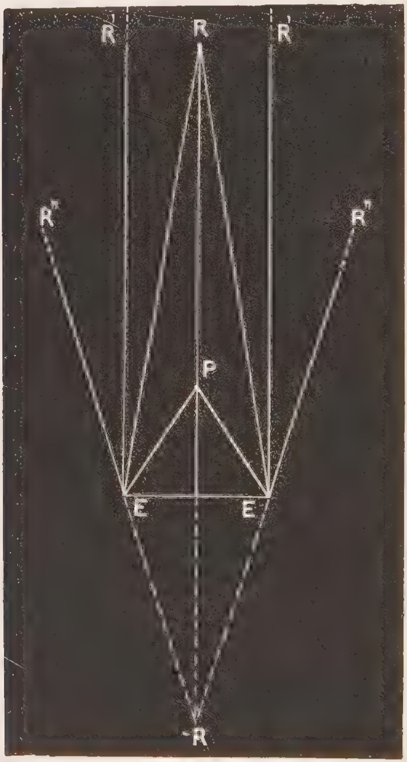


FIG. 27. (AFTER NAGEL AND LANDOLT.)

The Punctum Remotum of Convergence. — *Just as the punctum remotum of accommodation is the expression of the* refraction *of the eye when completely at rest, so the*

punctum remotum of convergence is the expression of the position *of the eyes when at rest—that is, when the impulse to fusion brought about by binocular vision is removed*—so that to find R we must find the *latent position* of the eyes for distance. This we do by the Maddox test, and the number of metre angles read off on the scale gives us "r." When there is no latent deviation "r" = 0, when there is latent divergence "r" is negative, and when latent convergence, it is positive.

To find "p," the maximum of convergence, we direct the person to fix binocularly a small test object held, say, one-third metre from the eyes, equidistant between them and on the horizontal plane of the eyes. This may be a fine hair or wire stretched vertically in a frame, or it may be a luminous slit, as in Landolt's ophthalmodynamometer (Fig. 28); when the object is approached to such a distance that the test line appears double, we measure off the distance in centimetres, and divide this into 100, which gives us the number of metre angles that "p" is equal to. Suppose "P" to be 10 cms., "p" = $\frac{100}{10}$ = 10 m.a., and if R be at infinity,

$$a = 10$$

but if there be latent divergence, say of 1 m.a., r = − 1 m.a., and

$$a = 10 - (-1) = 10 + 1 = 11 \text{ m.a.}$$

In this test we must be careful to distinguish between mere haziness of the test object, which is the result of its being within the patient's accommodation near point, and doubling of it, because the near point of convergence is often nearer than that of accommodation. We should, therefore, always first ascertain the accommodation near point in each eye.

It is generally considered that the normal amplitude of convergence 10. m.a., although it may be 15 or even 17 m.a.

The Relative Range of Accommodation and Convergence.—If the *latent* position of the eyes be tested, not only during the fixation of distant objects and of

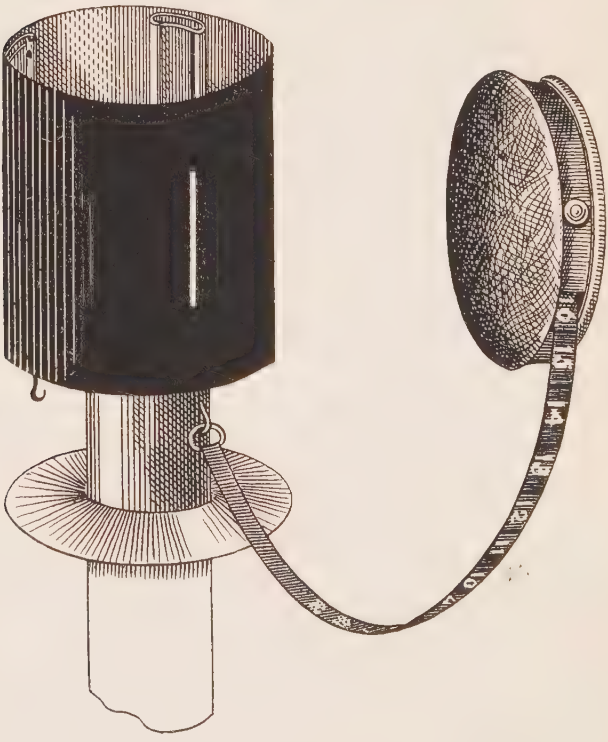


FIG. 28.—LANDOLT'S OPHTHALMO-DYNAMOMETER.

This apparatus rests on a candle, which, when lighted, causes the slit in the cylinder to appear as a luminous line.

objects at a reading distance, but also for intermediate distances of fixation, it will be found that, as a rule, there is quite a gradual lagging of the non-fixing eye behind the

fixing one: a *gradual* increase of latent divergence. This divergence is greater in myopia and less in hyperopia than in emmetropia. Fig. 29 represents the average curve of relative latent deviation in emmetropia. According to this figure we see that with parallelism, or a condition almost approaching to parallelism for distance, there is $\frac{1}{2}$ a metre angle of divergence on accommodating for

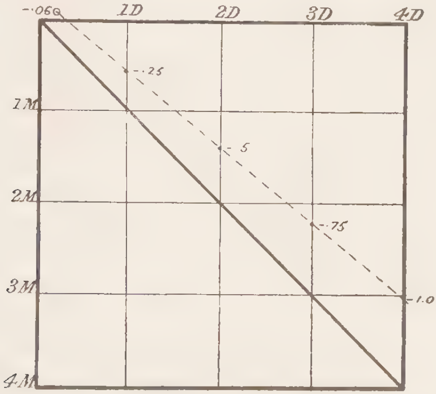


FIG. 29. (AFTER BERRY.)

$\frac{1}{2}$ metre, and a whole metre angle for $\frac{1}{4}$ metre accommodation—that is, that whereas, with both eyes fixing, on accommodating for $\frac{1}{4}$ metre, 4 D of accommodation is used, and both eyes converge to a point using 4 m.a. of convergence, when the possibility of fusion is removed both eyes only converge to a point $\frac{1}{3}$ metre off, using 3 m.a. of convergence.

This is no proof of the existence of "insufficiency" of convergence, all it shows is that the intimate relation between accommodation and convergence is not absolute.

All the more, then, should we expect to get latent divergence for near points when there is initial latent

divergence for distance. When there is initial latent divergence for distance, the "lagging" of the convergence behind the accommodation for near points is more marked than when the position of the eyes is parallelism, and this produces a "convergence insufficiency." We can ascertain the presence of latent deviation in near vision by the Maddox test. A scale (see plate, page 42) is held $\frac{1}{4}$ metre from the eyes, and a prism of 12°, base up, is held before the right eye. The scale consists of a horizontal line with fine print below it, in the centre of which is an arrow pointing upwards. The line is divided in degrees which are marked by figures, black on the right of the arrow, red on the left. Every $3\frac{1}{2}°$ from the arrow is marked by a small cross representing 1 m.a. The prism causes two lines and two arrows to be seen, and the patient is instructed to fix the upper arrow, or, better, the fine print just below it. When there is no latent deviation the two arrows are in a vertical line. When the lower arrow points to the left (red side) of the upper arrow there is latent divergence, and when it points to the right (black side) there is latent convergence for $\frac{1}{4}$ metre, the amount of deviation being read off on the scale. Graefe's "dot and line" test is inferior to the foregoing, as it does not record the amount of the defect.

Maddox maintains as a result of his experiments that in near binocular vision there is always relative divergence —that is, convergence always lags behind accommodation. This convergence is composed of three factors: (1) "initial convergence" (this, of course, exists only when there is latent convergence) due to the relaxation of the external recti which are maintaining parallelism, (*pp*, Fig. 30), and the eyes assuming their position of rest, *i i;* (2) accommodative convergence—*i.e.*, the amount of convergence which is called forth by the accommodative effort which brings the axes to *a a;* and, lastly (3),

the "fusion supplement," which is the result of the desire for single vision, and brings the axes to *o*. This "fusion supplement" is demonstrated by holding a pen midway before the eyes of a patient at the distance of the convergence near point, and telling him to fix the tip of the pen; if now one eye is covered, this covered eye will markedly turn out, and, on uncovering, the patient will for a moment have diplopia, the eye making an incursion to recover binocular vision. The amount of the excursion on covering, or incursion on uncovering, represents the fusion supplement which the demand for binocular vision

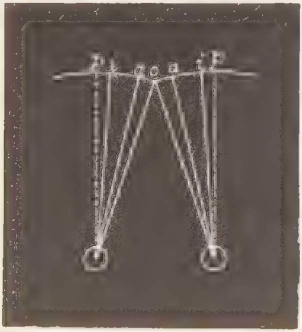


FIG. 30. (MADDOX.)

calls forth. This experiment can be made on most people, and is no proof of "insufficiency" of convergence.

Although accommodation and convergence are intimately connected, this connection is not absolute. We can prove this experimentally by altering our accommodation without changing our convergence, as in looking at an object with both eyes before which we place weak convex and concave glasses, and also by altering our convergence without changing our accommodation by placing before the eyes weak prisms, base in or out. The amount

of dissociation between the accommodative and convergence efforts is limited, and varies *with* and *in* the individual; it can be increased by practice, and it differs for varying degrees of accommodation and convergence. Fig. 31 shows the relative amount of accommodation that can be used with different degrees of convergence in an emmetrope aged 15.

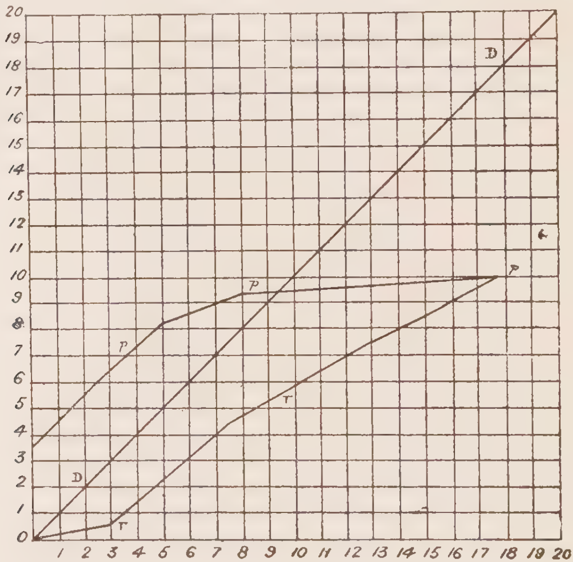


FIG. 31.

The horizontal figures record the degrees of convergence in metre angles, and the vertical figures record the degrees of accommodation in dioptres. The diagonal D D represents the convergence, starting from zero—*i.e.*, infinity—and stopping at 5 cms. (20 metre angles). The vertical divisions between the upper curved line *p p* and the diagonal represent the amount of maximum or positive part of accommodation

ascertained by the strongest concave glass that can be borne without prejudice to binocular and distinct vision for any given point of convergence, and those between the diagonal and the lower curved line *r r* represent the amount of minimum or negative part of accommodation ascertained by the strongest convex glass. Thus, take convergence for 6 m.a.: above we have 2.5 dioptres of positive accommodation, and below 3 of negative accommodation—that is, the relative amplitude of accommodation for 6 m.a. of convergence is 5.5 in this individual. It will be seen that when the convergence has reached 10 m.a. the whole of the range of accommodation is negative.

Accommodation remaining fixed, we can estimate the amount of relative convergence by means of prisms; the strongest prism, base out, that can be borne with fusion represents the positive, and base in, the negative part, of the amplitude of convergence, and, as Landolt has pointed out, we find that Fig. 31 can be made use of to represent this. The diagonal D D represents the accommodation starting with eyes adapted for infinite distance; the positive portion of the relative range of convergence is on the right of the diagonal, and is represented by the horizontal divisions between D D and *r r*, and the negative portion is on the left. Thus for accommodation at 25 cms.—*i.e.*, 4 dioptres, we see that we have 3 m.a. on the right and 3.5 m.a. on the left—that is, while maintaining the same amount of accommodation, an adducting prism producing a deviation of 3 m.a. and an abducting prism requiring a diminution of 3.5 m.a., can be overcome by the eyes. Thus for 4 dioptres of accommodative power in this individual, an amplitude of convergence of 6.5 m.a. exists.

It is fortunate for the ametrope that this dissociation between accommodation and convergence is possible. A hyperope of 3 D who fixes an object binocularly 33 cms. off must use an additional 3 of accommodation—that is, he must use 6 altogether—but he will only require to converge to 3 m.a. If the association between accommodation and convergence were absolute, he would either have to converge to 6 m.a. and consequently squint, and thus lose binocular vision, or he could keep binocular

vision on the condition that he did not accommodate for this near point; in other words, he has the choice between distinct vision and binocular vision—he cannot have both. Many hyperopes dissociate these two efforts, and can by practice and "nerve education" accommodate in excess of their convergence (see page 84). The difference in the power to dissociate these two efforts is the explanation of the well-known fact, that of two individuals having the same refractive defect, one will squint and the other not.

The same necessity for dissociation between convergence and accommodation occurs in myopia. A myope of 3 D can see an object 33 cms. off without any accommodation, but must converge to the extent of 3 m.a. Thus he uses his *convergence* in excess of his accommodation.

CHAPTER VI.

THE OPHTHALMOSCOPE.

To understand the action of the ophthalmoscope the following facts connected with the **Optics of Reflection** should be remembered.

1. When light falls on a plane mirror (A B, Fig. 32) the angle of incidence is equal to the angle of reflection.

The incident ray F D makes with the perpendicular

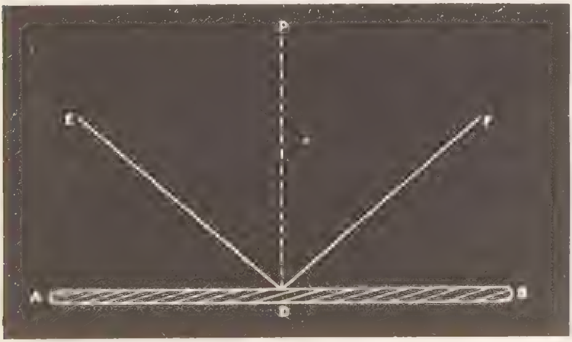


FIG. 32.

P D an angle F D P and the reflected ray D E also makes an angle E D P, and these two angles are equal to one another. Both incident and reflected rays are in the same plane, which is perpendicular to the mirror.

2. When parallel rays of light (Fig. 33, A B and C D) fall on a concave mirror they are reflected to a focus (F)

in front of the mirror, and this principal focus is midway between the mirror and the centre of curvature of the mirror (o) and on the principal axis.

3. Rays of light coming from a point near the mirror, but beyond its centre, as at L (Fig. 33), come to a focus (*l*) between the centre and the principal focus, and the two points are conjugate foci.

The Ophthalmoscope.

If by some contrivance we can manage to send rays of light from a spot in front of our eye into another eye, we

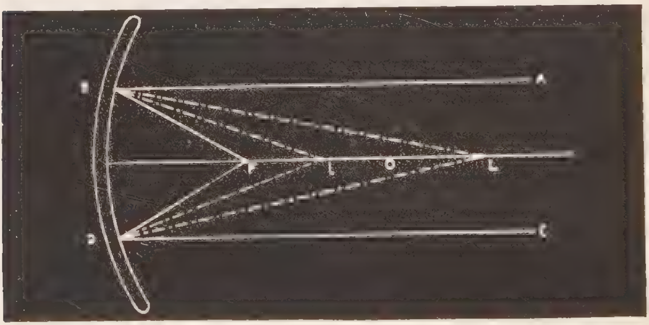


FIG. 33.

shall get some of those rays returning to our eye after being reflected from the retina of the observed eye, if the media be clear, and the pupil of the observed eye, instead of appearing black, will appear red.

This can be done in the simplest manner by a piece of glass plate. If *Obd* is the observed eye, and *Obr* the observer's eye (Fig. 34) in front of which is inclined a glass plate GL, the rays of light passing from L are reflected partly at GL into *Obd*, return along the same path, passing through the plate, and enter the observer's eye. As only a few rays find their way to the observer's

eye, the light is very feeble. This was the principle of Helmholtz's first ophthalmoscope, and he improved it by placing together several glass plates, and thus increasing the luminosity. If for these glass plates a mirror with a central hole is substituted, more rays still will pass into the eye, and these rays returning, more will pass through the hole in the mirror into the observer's eye, and a brighter image of the fundus will be seen.

If now the mirror is made concave, the light is more concentrated, and further improvement results. Such is the simple ophthalmoscope—viz., a mirror with a central sight-hole supported on a handle.

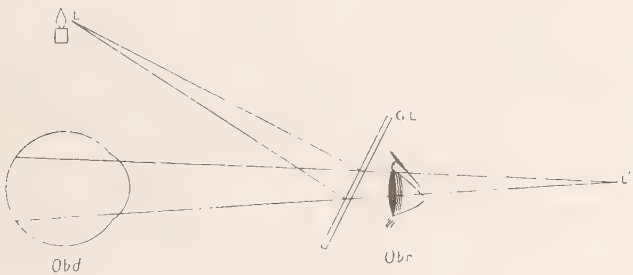


FIG. 34.

The ophthalmoscope has been further improved by adding an arrangement of lenses of different strength, which can be turned into position in front of the sight-hole, so that if the eyes of the observer or observed are ametropic, a clear image of the fundus can be obtained by the correcting lens.

The Qualities of a Good Refraction Ophthalmoscope.—The mirror should be concave, with a focus of from 14 to 17 cms. It should be oblique, and capable of being turned round so that it can be used for either eye. This obliquity of the mirror enables us to approach very near the observed eye without cutting off any of the light, and also permits the correcting glass, when used, to be in a position

parallel to the vertical plane of the eye. When the oblique mirror is not required, as in the "indirect" method and in the "shadow test," a "straight" mirror should be substituted for it. This can be done by changing the mirrors, or, better still, by an arrangement like the nosepiece of a microscope, to which both mirrors are attached, either of them being turned into position as required. A further improvement can be made by the "straight" mirror being plane on one side and concave on the other, and fixed with a spring hinge, so that either side of the mirror can be used as desired. The mirror

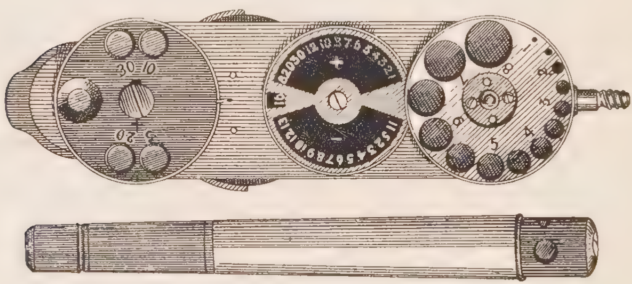


FIG. 35.—MORTON'S OPHTHALMOSCOPE.

The rotating wheel is made to serve as a pupillometer, the discs being numbered from 1 to 8 mm.

should be perforated; imperforate mirrors (with a central hole in the silvering) are not so good, as the glass reflects some of the light that should enter the observer's eye. The hole in the mirror should not be too small, otherwise too little light will reach the eye of the observer; its diameter should be about 3 mm. anteriorly (the glass side) and somewhat wider behind, and the sides of the tube should be well blackened. The correcting lenses of the ophthalmoscope should not be too small; they should have a diameter of not less than 5 mm. There should not be too many of them, and never more than two

superimposed. The best plan is to have the glasses ordinarily used set round the rim of one disc, and those less used arranged either on another disc or on a movable quadrant. The number of ophthalmoscopes on the market is large, but the best and certainly the most popular is Morton's (Fig. 35).

The focussing-glass used in the "indirect" method should have a focus of about 8 cms.—*i.e.*, be about 13 D —and should have a diameter of about 5 cms. The focussing lenses usually supplied with ophthalmoscopes are much too small. The glass should be kept clean and free from scratches.

The Different Methods of Examining the Eye with the Ophthalmoscope.

1. The indirect method.
2. The direct method.
3. The "shadow test," or retinoscopy.

The patient should be in a darkened room.

The light used should be on an adjustable bracket if possible; any kind of light will do if it has a broad, steady, white flame, but the electric light in a ground-glass globe is the best, as it gives off less heat.

Before commencing the ophthalmoscopic examination the eye should be thoroughly examined by the oblique or focal illumination. For this purpose put the light on a level with the patient's eye, on the same side as the eye to be examined, and about 12-15 inches from it, and with the focussing-glass throw a luminous spot on the cornea. By moving the lens about, the whole surface of the cornea, the anterior chamber, iris, and anterior surface of the crystalline lens can be examined. This examination is further aided by viewing the illuminated spot through a strong magnifying glass, and one of the best is Voigtlaender's. This preliminary examination gives

valuable information as to the translucency of the media, etc.

1. **The Indirect Method.**—Place the light close to the patient's head and a little behind, so that no light can reach the eye to be examined directly.

Use the "straight" concave mirror, holding it about 15 inches from the eye, thus lighting up the fundus, and making the pupil appear red (if the media are transparent), and detecting opacities of the cornea, lens, and vitreous (the latter are best seen with a plane mirror and faint light).

Still using the same mirror, put up the focussing-glass, holding it by the left index-finger and thumb, and steadying it by resting the remaining fingers of the left hand on the patient's brow. By this means an image of the fundus, which is real and inverted, is seen. This is called the indirect method.

The observer recognises that the picture is inverted by slightly moving his head or the focussing glass and finding that the image moves in the opposite direction.

The manner in which this inverted image is formed is shown by the following figures.

The focussing-glass held in front of the eye makes the eye myopic, and, according to the refraction of the eye, this inverted image will be nearer or further from the lens.

When the observed eye is emmetropic, the rays coming from the eye (Fig. 36, E) are parallel, and focus at the principal focus of the focussing-glass; and, moreover, as the rays emerging from the eye are parallel, it does not matter where the focussing-glass is placed; nearer or further from the eye, the image must necessarily always be the same size.

In hyperopia (Fig. 36, H) the rays emerging from the eye are divergent, and, passing through the focussing-glass, they form a larger image than in emmetropia, and this image is further from the lens *in front* of its principal

focus; on withdrawing the lens from the eye the image is formed on the other side of the lens, nearer and smaller.

In high hyperopia the image is so far in front of the focussing-glass that the observer will have either to move back or to accommodate in order to get a distinct view of the inverted image.

If with the mirror alone, still held at some distance from the eye, we can recognise fundus details not inverted, that is in their true position, we are dealing with *high hyperopia.*

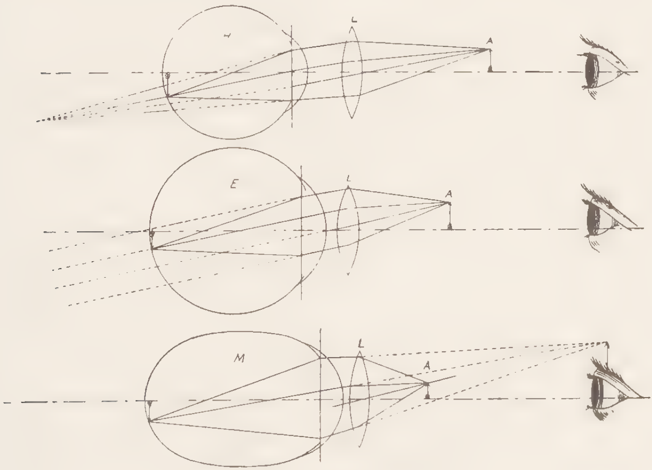


FIG. 36. (AFTER FICK.)

In myopia (Fig. 36, M) the rays emerging from the eye are convergent, and form an inverted aerial image in front of the eye, and the focussing-glass shows this image smaller than in emmetropia, and nearer to the lens—in fact, within its principal focus; on withdrawing the lens the inverted image becomes larger.

In high myopia no focussing-glass is required to see the fundus, as the rays proceeding from the eye are so

convergent that they come to a focus at the punctum remotum and form an inverted image.

In astigmatism the disc may appear oval, and the shape will alter as the focussing-glass is withdrawn, according to the refraction of the different meridians.

The advantages of the indirect method are:

1. The examiner is further from the patient than in the direct method (a distinct advantage in dealing with certain patients).

2. A general "bird's-eye" view of the fundus is obtained.

3. No correcting glasses are needed in the ophthalmoscope; thus a simple concave mirror with a central hole is sufficient.

4. It is sometimes easier to see the fundus when the pupil is small.

In looking at the right disc the patient should be directed to look past the observer's right ear, for the disc is on the nasal side of the posterior pole of the eye, and on looking at the left disc he should look past the left ear. It is important to remember that the patient must look with the eye *not* being examined; therefore in examining the left eye by this method take care not to obscure the right eye with the hand that is holding the focussing-glass.

2. **The Direct Method.**—The light must be brought quite close to the patient's head and slightly behind, and on the same side as the eye to be examined. The observer sits (or stands in a stooping position) close to the patient, and on the same side as the eye to be examined, using his right eye for the patient's right eye, and his left for the patient's left.

Use the refraction ophthalmoscope (without the focussing-glass) and the oblique concave mirror. Holding the ophthalmoscope a few inches from the eye, reflect the light on to the eye and observe the red pupillary reflex

through the central hole of the mirror, and then, without allowing the light to leave the eye, approach the eye as near as possible—in fact, the observer's forehead ought to touch the patient's forehead. The fault that most beginners make is not getting near enough to the eye. The observer must not accommodate, but look, as if trying to see through the patient's head, into distance. If the observer or patient have an error of refraction, the wheel of the ophthalmoscope must be turned until the suitable glass is found. To see the macula, the patient should be told to look horizontally, in front; if the disc is to be examined he should look slightly to the nasal side.

Only a small portion of the fundus can be seen at one time, but this portion is considerably magnified (about 15 diameters), and consequently the minutest details are visible.

By this method the refraction of an eye can be estimated, which as an objective method has, of course, a distinct advantage.

The first duty of the observer—and most beginners find this very difficult—is to relax his accommodation. The person whose eye is being examined must also relax his accommodation, which can be done by directing him to look at some object 5 or 6 metres off with the other eye, or, better, by paralyzing the ciliary muscle with a cycloplegic. If both the observer's and the observed eye are emmetropic, all the details of the fundus will be clearly seen. We can easily understand this when we remember that rays passing from the mirror to the back of the eye that is being examined, are reflected as parallel rays if the eye be not accommodating and be emmetropic, and that parallel rays must be focussed on the fundus of the observing eye if it also be emmetropic, and its accommodation be relaxed (Fig. 37). If, on the other hand, the observer's eye under these circumstances accom-

modate, the image, instead of being sharp, is blurred. It is not only necessary to observe these rules in order to get a clear picture of the fundus, but it is of paramount importance if we wish to estimate correctly the refraction of the eye we are examining. For this reason it is important that the observer should estimate his own refraction, and, if there be any error, correct it.

If the observer be myopic, the fundus will be indistinct, just as is the case with all distant objects, for the rays coming from the observed eye are parallel—that is, as if coming from a distant object. In order, therefore, to obtain a clear view of the fundus the myope must use a

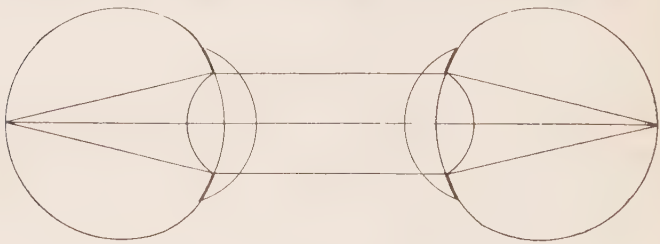


FIG. 37.

concave glass, and the weakest concave glass he can see distinctly with, will be the measure of his myopia, if his accommodation be relaxed.

A hyperopic observer is in a somewhat better position, because he can see the fundus if he accommodates; but as he must relax his accommodation in order to estimate the refraction of the eye he is examining, he must first find his own refractive defect and correct it. Unless he had his defect properly corrected in early youth, he has become so accustomed to use his accommodation, that it will be most difficult—almost impossible—for him to relax it, and the probability is that, although the convex glass he uses corrects his defect, he nevertheless cannot

help using some accommodation, and will thus over-correct himself, rendering himself myopic. It necessarily follows, therefore, that it is most difficult for a hyperope to estimate the refraction of an eye correctly, by this method. He should use some other method, such as the "shadow test," which will be explained later.

We have supposed up to now that the observed eye was emmetropic. We will proceed to examine the conditions that exist when the observed eye is myopic or hyperopic.

Examination and Measurement of a Myopic Eye by the Direct Method.—The retina of a myopic eye is at the conjugate focus of an object situated at finite distance (see page 93); consequently rays proceeding from the retina of a myopic eye are focussed at the far point when the accommodation is relaxed. Now, as this far point is at finite distance—in fact, near the eye—the rays are convergent; consequently they will not be focussed on the retina of an emmetropic eye unless they are made parallel by using in the ophthalmoscope a suitable concave glass. This is done by turning the wheel of the instrument and bringing concave glasses before the opening, and the weakest concave glass required is the measure of refraction (if the accommodation of both the observer's and the observed eye is relaxed).

The observer will, of course, be able, by using his accommodation, to see the fundus with a stronger concave glass than is required, but he will not then be able to measure the amount of myopia. If the observer be a myope, and his myopia be not corrected with glasses, to ascertain the refraction of the observed eye he must deduct from the concave glass he requires, the amount of his own myopia. When, for instance, the weakest concave he requires to see clearly the retina of the myopic eye is -5, and he himself is -2, then the observed eye is -3. When he is hyperopic, he must add the amount of his hyperopia—*i.e.*, when he has hyperopia of 2, and the

weakest glass he requires is − 5, the amount of myopia in the observed eye is − 7.

The Examination and Measurement of a Hyperopic Eye by the Direct Method.—The rays emerging from a hyperopic eye are divergent (see page 79), and as they must be made parallel for an emmetropic observer if he wish to see the fundus clearly, a convex glass, representing the amount of hyperopia, must be turned into position. If the patient have hyperopia of 4, then + 4 must be used. The fundus could be seen clearly without a glass by accommodation; but, then, as it would be impossible to measure the amount of accommodation used, so would it be impossible to estimate the amount of hyperopia in the observed eye.

A hyperope who is examining a hyperopic eye with the ophthalmoscope, must deduct the amount of his own hyperopia from the strongest lens he requires to see the fundus with—*i.e.*, if he be hyperopic to the extent of 3, and the strongest convex glass he can clearly see the fundus with is + 6, the observed eye has a hyperopia of 3 D.

A myope, on the other hand, as he requires a weaker correcting glass, must add in dioptres the amount of the defect; thus, when he is *myopic* to the extent of 5, and requires no glass to see the fundus well with, the eye that is being examined is *hyperopic* to the extent of 5. Again, when his myopia is 3, and the strength of the convex glass he can use is 2, the amount of hyperopia present in the observed eye is 5; or when he has myopia of 7, and he cannot see the fundus clearly with any glass less concave than 3, the amount of hyperopia present is 7 + (− 3)—*i.e.*, 4 D.

To put the matter a little more clearly, we may say that if an ametrope, to see clearly the fundus of an eye with the ophthalmoscope and to estimate correctly its refraction, require—

(1) A glass of the same kind as his own ametropia, but stronger, he must deduct the number of his own from that glass.

Example.—He has a myopia of 3 and requires -5 in the ophthalmoscope, then the error of the observed eye is -2.

(2) A glass of the same kind, but from one to ten dioptres weaker than his own ametropia, then the eye that is being examined has an ametropia of from one to ten dioptres of the opposite kind.

Example.—He has a myopia of 6, and requires -5; the refractive defect of the observed eye is $+1$. If he require -4, it is $+2$, and so on. He has hyperopia $+4$, and requires $+3$; then the refractive error of the observed eye is -1.

(3) If the glass required in the ophthalmoscope be not of the same kind and strength, the refraction of the observed eye is the opposite to that of the observer's, and the amount is equal to the addition of the number of dioptres of each.

Example.—He has myopia of 5, and requires $+3$; the refraction of the observed eye is $+8$. He has hyperopia of 3, and requires $-$ the error is -5.

It should be borne in mind that, to insure the exact measurement of the patient's refraction by means of the ophthalmoscope, the yellow spot must be looked at. If the patient be *not* under the influence of a mydriatic, this is not always easy, for not only does the pupil contract when the examined eye is turned towards the mirror, but the light reflex from the cornea interferes very much with the view; and, further, the absence of any large structure, such as the retinal vessels, makes it difficult to secure the correct focus. As a rule, all we see at the macula is a slight stippling, produced by the irregular deposit of retinal pigment, and when this pigment is specially pronounced we get a bright ring or crescent at the fovea. This is the fovea reflex, and

although the reflex is slightly in front of the retina, the distance is so small that it can be ignored, and this fovea reflex can be focussed and made use of in this manner, for ascertaining the refraction. If it cannot be used in this way, through being too faint, we must try and focus a small retinal vessel passing from the disc to the macula.

The beginner will find that the easiest part to focus is the temporal side of the disc, for its margin here is generally very well defined.

The Measurement of Astigmatism.—Astigmatism is revealed ophthalmoscopically by portions of the fundus picture being out of focus, and by our inability to get a clear picture of all parts at the same time by any of the spherical glasses in our ophthalmoscope. Some ophthalmoscopes have cylindrical glasses fixed in them, but this is not at all necessary, as the astigmatism can be approximately estimated without much difficulty by measuring the refraction of the meridians at right angles to each other in the following manner: Focus, for instance, the vessels that pass in a horizontal direction from the disc to the macula, and note the glass in the ophthalmoscope (the weakest concave and strongest convex) that is required to give them a clear definition; this will give the refraction of the meridian at right angles to the horizontal one—viz., the vertical. Then focus the vessels that pass vertically upwards and downwards from the disc; this will give the refraction of the horizontal meridian, and the difference between the two glasses (if any) is the astigmatism (if any).

When the chief meridians are not vertical and horizontal, but oblique, we can then, say, focus the vessels passing upwards and outwards from the disc, and when we have focussed these vessels, if astigmatism exist, the vessels passing downwards and outwards will not be in focus,

but will be either blurred or invisible, and we proceed to find the glass that is necessary to bring these latter vessels into focus, and so on. If the correcting glass be a large one, we must be careful to look through the centre, for if we look through the glass obliquely we shall get an appearance as if produced by astigmatism, which might not be present.

In estimating the refraction by means of the ophthalmoscope, as above explained, the observer should approximate his eye as much as possible to the eye that is being examined, as the value of the lens is altered by altering the distance; a concave glass is weakened and a convex glass strengthened by removal from the eye. It is for this reason that old people are often seen to wear their glasses low down on the nose, the strength of the convex glass being slightly increased. This, of course, specially refers to lenses of high power; therefore the further away we hold the ophthalmoscope the more shall we over-correct in myopia and under-correct in hyperopia—*i.e.*, the myopia of the eye being examined will be less, and the hyperopia more, than that represented by the ophthalmoscope glass.

3. **The Estimation of the Refraction by the "Shadow Test"; Retinoscopy; Skiascopy.**—Seated at a short distance from the patient in a dark room, if we throw the light on to the patient's eye by means of an ophthalmoscopic mirror, provided the pupil is normal and the media are clear, we observe the red reflex of the fundus, and if we gently rotate our mirror, the red reflex disappears, and darkness takes its place. The manner in which this darkness or shadow appears varies according to the refraction of the eye.

We will examine the behaviour of the shadow under three conditions:

1. When the observer is beyond the patient's far point.

2. When he is *within* the patient's far point.

3. When he is exactly at the patient's far point.

1. Let us suppose the surgeon *ob* (Fig. 38, A) examining the patient PT by this method, and using the plane mirror, and we will assume PT to have a refractive error of over 1 of myopia. *ob* is seated 1 metre off PT, and is consequently beyond PT's far point. *ob* reflects the light into PT's eye and observes the red reflex, and if he rotate the mirror, making the light pass, say, across PT's face from the nose to the temple, he will notice that the red reflex disappears, and that darkness takes its place, and in this example the darkness or shadow comes over the eye from the temple towards the nose—that is, in the opposite direction to the rotation of the mirror.

Let us see how this has come about. In Fig. 38, for the sake of clearness, the mirror and the light have been omitted, and only the rays proceeding from PT's fundus have been drawn.

All luminous rays proceeding from the fundus of PT through the pupil P*p* (Fig. 38, A) either do not reach the eye *ob*, or they impinge on *ob*'s retina between P′ and *p*′. Thus, all rays from *p*, from whatever part of PT's fundus they come, must unite at *p*′ of *ob* if they are intercepted by *ob*'s pupil.

Let *a* be a luminous point on the fundus of PT (who in this case is assumed to have a myopia of over 1), then at PT's far point, somewhere on the line between *a* and the nodal point, an aerial image *a*′ of *a* will be formed. Some of the diverging rays from *a*′ will reach *ob*, and, passing through the refractive media, will unite at *a*″; but as *ob*'s fundus intercepts these rays, a bright diffusion circle will be formed on the upper part of P′ *p*′ (*ob*'s fundus), while the lower part of P′ *p*′ will be in darkness. Now, as our retinal images are projected inverted, *ob* sees the pupil of PT light below and dark

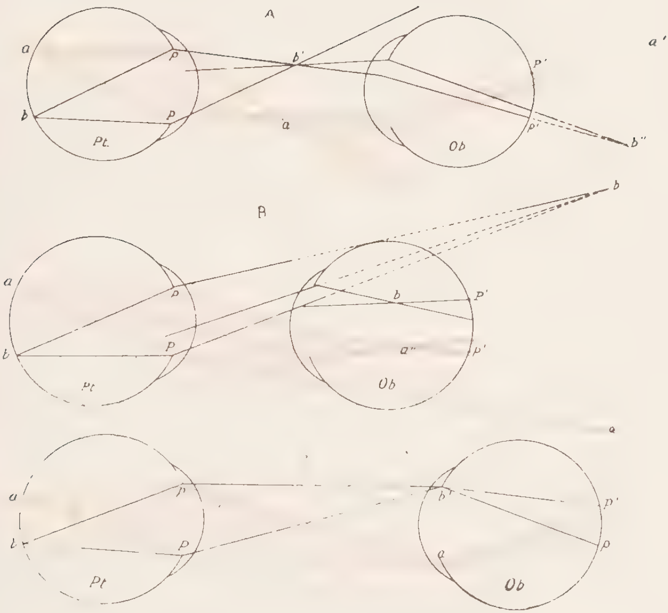


FIG. 38. (AFTER FICK.)

To face page 70

above. If the luminous spot *a* descend to *b* in P*t*, its image ascends to *b*′, and we have a bright area below in P′ *p*′, and O*b* sees in P*t*'s pupil a bright area passing *from below upwards.*

We thus see how in myopia of over 1 D, with the observer 1 metre from the patient, and using a plane mirror, the " shadow " moves *against* the rotation of the mirror.

2. The reverse obtains when O*b* is *within* P*t*'s far point. Let us suppose (Fig. 38, B) P*t* to be hyperopic. The image of *a* will be at *a*′, but those rays that pass through O*b*'s pupil are refracted, and meet at *a*″ in front of the retina, and, diverging again, meet O*b*'s retina at *p*′ as a diffusion circle; in this case the bright area being below is projected inversely, and O*b* sees P*t*'s pupil bright above and dark below, and if *a* moves down to *b*, it will be seen that O*b* projects the bright area moving down also. Thus, with a plane mirror, if O*b* be within P*t*'s far point, the shadow moves *with* the mirror; if O*b* be seated 1 metre off P*t*, this will occur in hyperopia, emmetropia, and myopia of less than 1 D.

3. Lastly, let us consider what happens when O*b* is exactly at P*t*'s far point, which, of course, occurs if O*b* be seated 1 metre off P*t*, who has a myopia of 1 D (Fig. 38, C). The illuminated point *a* has its image *a*′ exactly on the pupil of O*b*, and as the ray *p a*′ is refracted to *p*′, and the ray P *a*′ to P′, the entire area P′ *p*′ is illuminated, and the entire pupil of P*t* appears illuminated to O*b*. Movement of *a* to *b* produces no effect; the area P′ *p*′ is still illuminated; but when the luminous point on P*t*'s retina passes below *b* or above *a*—that is, outside the area *a b*, it is focussed on O*b*'s iris, and no rays reach O*b*'s retina; consequently O*b* sees the pupil P *p* becoming *suddenly* dark, and there is *no* moving shadow. This point, when the observer's eye is exactly at the patient's far point, is called the point of

reversal, and the whole principle of retinoscopy is to find this point. In myopia *ob* can move nearer to or further from the patient, and measure off the distance of the point of reversal, and so obtain the refraction of that particular meridian; but in hyperopia this cannot be done, so that the best method is to work always at one fixed point—say 1 metre—and make the patient artificially myopic, if hyperopia or emmetropia exist, by placing before Pt's eye convex glasses; if he be myopic, make him less myopic by using concave glasses.

Let us now examine a patient. The patient's eyes should (if possible) be under the influence of a cycloplegic, which not only gives us a dilated pupil and makes the retinoscopy easier, but ensures the relaxation of the ciliary muscle, which, of course, is essential. The patient should be seated in a dark room, with the light above or on one side of his head and slightly behind, so that no rays can reach the eye except from the mirror. We provide ourselves with a set of test lenses and a trial frame, and seated, say, 1 metre off the patient, we reflect the light by means of the plane mirror into the patient's eye, directing him to look at the sight-hole of the mirror. Suppose we are examining the right eye, and rotate the mirror so that the light passes across from the patient's nose to the temple, and suppose we notice that as the light leaves the pupil a dark shadow takes its place, passing across in the same direction—*i.e.*, from the nose to the temple—we know from Fig. 38, B that we are *within* the patient's far point, and that we are dealing with a hyperope or emmetrope, or myope of less than 1. Let us place in the trial frame +2: we find, say, that the shadow is still moving *with* the mirror; we are therefore dealing with Hyperopia. Put up +4: the shadow now moves against the mirror, which means we are outside the patient's far point; we put up +3, and we find on rotating the mirror that the pupil becomes suddenly dark, and there

is no shadow following with the rotation, or passing against it. This, then, is the point of reversal. We have found the point of reversal with a + 3 lens, seated 1 metre from the patient, which means that this meridian has a myopia of 1 with a + 3 lens in front, and, deducting 1 from 3, leaves us 2 as representing the hyperopia. If our patient be emmetropic in this meridian, a + 1 lens will give us the point of reversal at 1 metre.

If the patient's eye have a myopia of over 1, when we are seated 1 metre off we must be outside his far point, whatever the amount of myopia, and the shadow moves "against" the plane mirror, and that glass which gives us the point of reversal represents the amount of myopia of that meridian with 1 added if we are seated 1 metre off (or 2 added if seated 50 cms. off, or .5 added if 2 metres off)—that is, if – 5 gives the point of reversal, – 6 is the amount of myopia. Some surgeons always aim at reversing the shadow—that is, they purposely go beyond the point of reversal and slightly over-correct. This is quite safe if allowance be made for the over-correction.

In our examples we have been ascertaining the far point of one meridian only—viz., the horizontal; we must now proceed to examine the meridian at right angles —viz., the vertical, and if the same glass give us the point of reversal, we know that no astigmatism is present; but if there be a difference, that difference represents the astigmatism. When the astigmatism is great, and especially when one meridian is emmetropic or made emmetropic, the light is seen to pass across as a bright band (Fig. 39), and sometimes two bright bands are seen with a dark band in the centre, and as the bright bands approximate each other, the central dark band disappears, and one bright band remains. This has been called the "scissor movement."

In oblique astigmatism, of course, the meridians are

not vertical and horizontal, and when the astigmatism is marked, the appearance of the shadow is very characteristic, and a bright band is seen passing obliquely across the pupil, although we may be moving our mirror horizontally or vertically (Fig. 39). Suppose we are dealing with oblique mixed astigmatism, and suppose we rotate our mirror horizontally, and observe a bright band followed by a shadow passing obliquely across the pupil "with" the plane mirror, we note the axis of this bright band, and also note that the meridian is hyperopic; now if we rotate our mirror at right angles to this bright band, we find we have a shadow passing against the move-

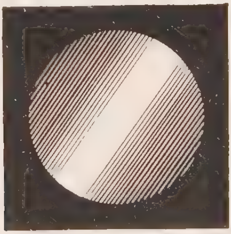


FIG. 39.

ment of the mirror, showing that this meridian is myopic. Suppose the point of reversal of the horizontal oblique meridian is obtained by $+3$, and that of the vertical by -1, by what we have seen we know that the refraction of the horizontal meridian is $+2$, and that of the vertical meridian is -2.

The greater the ametropia the nearer is the far point to the eye, and it is of great practical importance to remember that, the greater the ametropia, the less distinct is the shadow and the slower it moves; and as we approach the point of reversal by using correcting glasses, we obtain an increasingly defined shadow which moves more and more rapidly. We can thus, at once,

make a rough estimate of the degree and kind of ametropia.

In Fig. 40, if R be the far point of the myopic eye, on rotating the mirror, the shadow moves from R to R′; but if the myopia be less, and the far point at M, the shadow

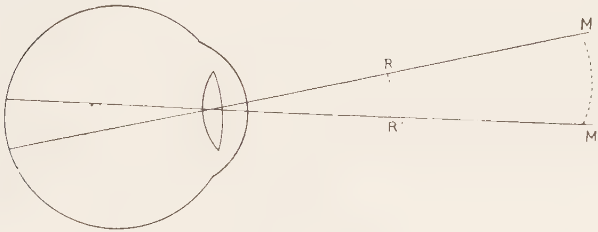


FIG. 40.

will have to describe the larger arc M M′ in the same time—that is, it will move more quickly.

In the same way, if the far point of a hyperope be at R (Fig. 41), the shadow will move more slowly than when the hyperopia is less and the far point at H.

Some surgeons use the plane mirror at a distance of

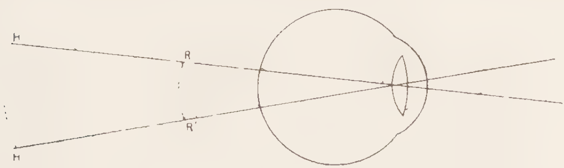


FIG. 41.

4 metres always, and as only .25 D has to be deducted from the retinoscopy, this small amount can be ignored, and the point of reversal of a meridian represents the measurement of that meridian.

When the surgeon is nearer than 1 metre, he must, of course, deduct more than 1. For instance, suppose at

33 cms. the point of reversal of a meridian is obtained with + 5, as his far point is $\frac{1}{3}$ metre off, we have made our patient artificially myopic to the extent of 3, and we must deduct this from 5; therefore 5 - 3—that is, 2, represents the hyperopia of this meridian.

Many surgeons still use the concave mirror. The mirror should have a focus of 25 cms., and the observer should be seated a little over a metre from the patient. The movement of the shadow is the reverse of that which takes place with the plane mirror—that is, the shadow moves "with" the mirror in myopia of over 1,

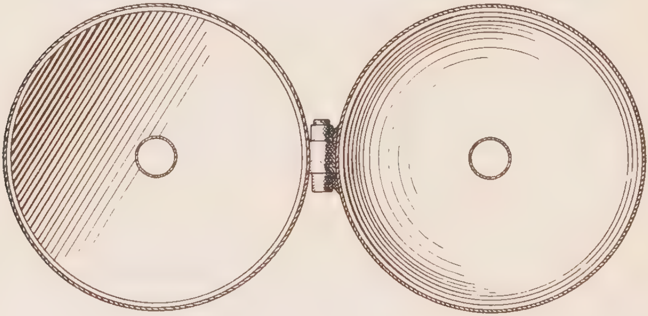


FIG. 42.

and "against" the mirror in myopia of less than 1, and in hyperopia and emmetropia. This is easily understood if we remember that, with a concave mirror, the rays of light converge to the focal point of the mirror and then cross and diverge; consequently the image thrown on a screen by a concave mirror is inverted. [If we reflect a lighted candle on to a dark screen by a concave mirror held further from the screen than its focal distance, and if we then focus the divergent rays with a convex lens, we shall get an erect image, because the rays have been twice inverted, whereas with a plane mirror used in the

same manner we obtain an inverted image, because there has been only one inversion.]

If the observer be not emmetropic he must wear his correcting glass, or make the necessary allowance in his calculations; for instance, if he have a myopia of 2 D, and be not wearing a – 2 glass, he must add –2 to the result, so that if the meridian appear to be myopic to the extent of 2, it is 4; if it appear hyperopic to the extent of 3, it is 1.

As the point of reversal is more definite when the shadow moves "*with*," it is not a bad plan to use a plane mirror when estimating hyperopia, and a concave mirror

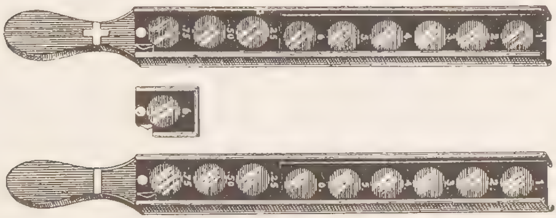


FIG. 43.—MARPLE'S SKIASCOPES.

when estimating myopia. These two mirrors can be hinged together, and thus each mirror is the handle and cover of the other (Fig. 42).

Marple's skiascopes (Fig. 43), made by Meyrowitz of New York, are very useful, and obviate the necessity for keeping a separate test case in the dark room; they are designed to be held by the patient before the eye during retinoscopic examination. Each contains a series of six lenses, ranging from 1 to 6 dioptres, plus and minus respectively. In addition to these lenses there is on one side a movable slide containing a 6 D lens, which can be quickly slipped up over the other lenses one after the other, making further combinations from 7 D to 12 D. To

determine smaller errors within I D, a slide containing three lenses, 0.25, 0.50 and 0.75 D respectively, is placed on the other side, and can easily be brought before the other lenses. On the skiascope containing the plus lenses the movable slide carries minus fraction lenses and *vice versâ*

CHAPTER VII.

HYPEROPIA.

Hyperopia or Hypermetropia.—The hyperopic eye is the flat or undeveloped eye in which, with accommodation at rest, parallel rays come to a focus beyond the retina (Fig. 15, H), and only convergent rays focus on the retina; but as in nature all rays are either parallel or divergent, it follows that the hyperopic eye at *rest* sees everything indistinctly.

The punctum remotum of a hyperope is beyond infinity; it is the point towards which the luminous rays ought to converge in order to be focussed on the retina; hence it is *behind* the eye, and is therefore represented as negative—viz., $-$ R (Fig. 44)—being the virtual and not the actual focus of the distant rays.

Rays coming from a point on the retina diverge, and, on passing through the dioptric system, emerge from the normal eye as parallel rays. In hyperopia, although they are not so divergent as they were before refraction, they still diverge if the eye be at rest, and therefore never come to a focus in front of the eye; but when prolonged backwards, they will meet at a point behind the eye, $-$ R, the punctum remotum (Fig. 44). The more convergent the rays are outside the eye, the nearer will their "backward prolongation" focus, hence the nearer $-$R is to the eye, the higher will be the hyperopia.

This is the same as we shall find in myopia—viz., the

higher the myopia, the nearer is R to the eye; but the difference is that in myopia R is in front of the eye, and in hyperopia it is an imaginary point behind the eye.

Thus, the degree of hyperopia is in inverse ratio to the distance of the punctum remotum. In myopia this point can be measured directly, but in hyperopia we can only do so indirectly by employing convex glasses.

Suppose the punctum remotum of a hyperope is 33 cms. behind the retina. We have seen that a convex lens whose focal point is 33 cms. is 3 D—that is, such a lens has the

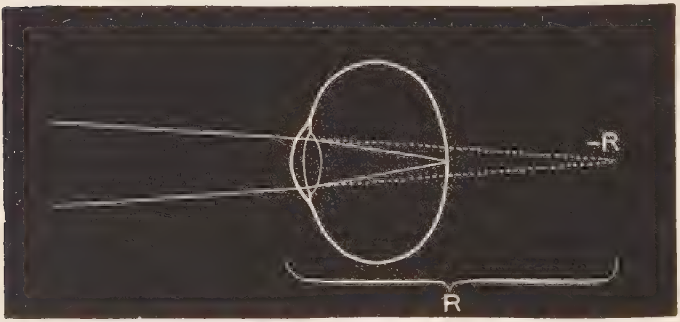


FIG. 44.

Showing the punctum remotum of a hyperopic eye.

power of converging parallel rays to a point 33 cms. on the other side of the lens, and conversely rays diverging from a point 33 cms. in front of such a lens become parallel on passing through. If this lens be put in front of the eye of this hyperope, it will so act that, assisted by the dioptric system of the eye, it will cause parallel rays to focus *on* the retina. Hence the measurement of hyperopia is that convex lens which enables the hyperopic eye, at rest, to see distinctly objects at infinite distance, and the focal distance of such a lens represents the distance of the virtual far point from the eye. In the

above example we found that + 3 was this lens, and we accordingly say that this eye has a hyperopia of 3.

Now, a hyperope differs from a myope in that he can correct his defect up to a certain point; he can by accommodation produce the same effect on parallel rays as if a convex glass where placed in front of the eye. This apparent advantage brings with it many disadvantages—viz., all the troubles incident to eyestrain.

The hyperopic eye is never at rest; it has to accommodate for distant as well as for near objects. The

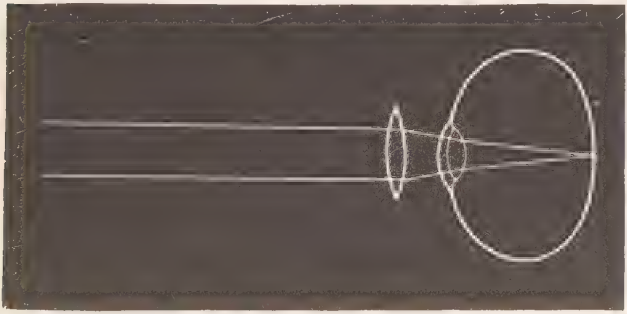


FIG. 45.

Showing parallel rays focussed on the retina of a hyperopic eye by means of a convex lens.

emmetrope's ciliary muscle is at rest when he is looking at anything beyond 20 feet, but the hyperope's eye is never at rest if he attempt to see distinctly; and, moreover, when he wishes to look at a near object, he starts with a deficit, which deficit is the amount of accommodation he required for distant vision. Thus, a hyperope of four dioptres, with five dioptres of accommodation, can focus distant objects clearly, but then he has only *one* dioptre left for near vision; this will only bring his near point to 1 metre from the eyes. Again, take a hyperope of two dioptres, with five dioptres of accommo-

dation, he has only three dioptres available for accommodation of near objects; this brings his near point to 33 cms., but he is using the whole of his accommodative power for this, and it is impossible for him to do this for long, without fatigue, and so we get all the symptoms of accommodative asthenopia.

We have seen that in hyperopia $a = p - (-r) = p + r$

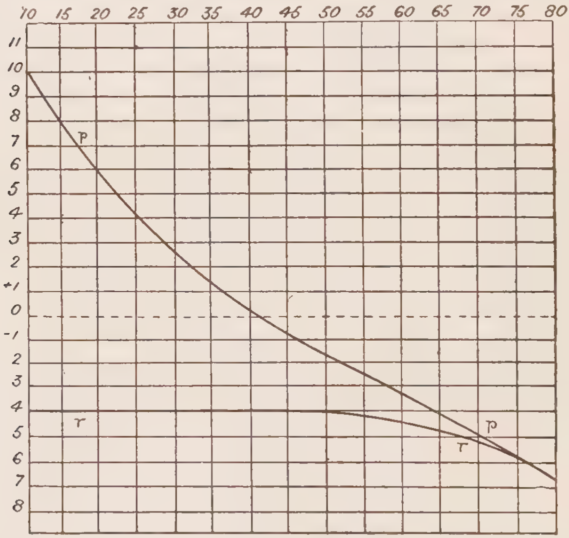


FIG. 46.*

Showing the range of accommodation of an uncorrected hyperope of 4 D at different ages.

(page 33), therefore $p = a - r$; in other words the *available* amount of accommodation power is represented by the total accommodation power less the amount required to correct the hyperopia, so that although, as we have seen, age for age the hyperopic eye has the same total amount

* The numerals above represent years, those on the left, dioptres. The line *p p* represents the curve of the punctum proximum, and the line *r r* that of the punctum remotum

of accommodation power as the normal eye, it has less to use for near vision, if uncorrected. In Fig. 46 the amount of available accommodation power in the uncorrected hyperope of 4 D is represented by the number of dioptres between *p* and the zero line; thus, at the age of thirty we find only two and a half, representing 2.5 D of accommodation power, because, although he has 6.5 D total power like the emmetrope, 4 of this is used up to correct his defect. At the age of forty we see that *p* crosses the zero line; in other words, all available power is lost. He has 4 D left, but this is used up in correcting his defect. Beyond this age he loses still more accommodation power, and this means that he cannot even correct his defect; in other words, he cannot obtain clear images of anything far or near.

This condition of affairs will obtain, of course, at an earlier age if the hyperopia be higher. Thus, a hyperope of 10 D at twenty-five has only 8 D accommodation power, and consequently sees everything indistinctly. Such persons very often approach their eyes very near their work in order to obtain larger retinal images, and an erroneous diagnosis of myopia is liable to be made.

The Varieties of Hyperopia.—The hyperopia which is at once recognised, the patient at once confessing to improved vision with a convex glass, is called manifest, and this manifest hyperopia (Hm) is expressed in amount by the *strongest* convex glass the patient accepts. For instance, a patient sees $\frac{6}{9}$, but with + 1 in front of the eye $\frac{6}{6}$: + 1.5 makes the letters hazy, then + 1 D = Hm.

Again, when the defect is hidden by the patient using his accommodation and obtaining perfect distant vision, the manifest hyperopia is represented by the strongest convex glass with which he can see equally well as with the naked eye. (The emmetrope and myope will not accept any convex glass for distance.)

The latent hyperopia is the additional hyperopia, which

shows itself when the accommodation has been relaxed with atropine. If the patient quoted above, when under atropine, see $\frac{6}{6}$ only when + 3 is used, in his case + 2 represents the latent hyperopia (Hl), the total hyperopia (Ht) being the sum of Hm and Hl. Hm + Hl = Ht.

Thus:

Total Hyperopia (*Ht*)	Latent H. (*Hl*) ..	Only revealed under a cycloplegic.
	Manifest H. (*Hm*) ..	*Absolute* (Hma), which no amount of accommodation can correct, represented by the weakest convex glass.
		Facultative (Hmf), when distant objects can be clearly seen with or without convex glasses, represented by the difference between the strongest and weakest convex glass.

The want of harmony between the accommodation and convergence efforts is a constant cause of asthenopia in uncorrected hyperopia. We have seen (page 44) that in the normal eye, the two eyes converging for a point 1 metre off, form a metre angle, and use 1 D of accommodation. Eyes converging for a point 50 cms. off have to converge 2 metre angles and accommodate 2 D, and so on. Now, a hyperope of 2, when looking at a point 33 cms. off, is using $\frac{100}{33}$—*i.e.*, 3 D added to the correction of his hyperopia—viz., 3 + 2 = 5 D; but he is only converging 3 metre angles instead of 5, consequently he is using 2 D of accommodation in excess of convergence.

Nature has endowed many hyperopes with the power of increasing their accommodation, *to a certain extent*, without varying their convergence; this faculty is the result of "nerve education." We shall see when dealing with myopia that the same thing occurs, only in this case it is the convergence that is used in excess of the accommodation. There is a minimum amount of effort when convergence and accommodation work harmoni-

ously together, as it were supporting each other; but when one is used in excess of the other, it has to work unaided and alone, and strain is liable to ensue.

Many hyperopes never learn this trick, as we may call it, of using their accommodation in excess of convergence, and therefore they are less likely to suffer from strain (although the unconscious effort to do so may induce it); but a worse evil befalls them—they lose binocular vision, and squint. A hyperope, under these circumstances, finds himself in the following dilemma: if he wish to see binocularly, he must use less accommodative power than he requires to see distinctly, or, if he wish to see distinctly, he must sacrifice binocular vision, which ends in squint. He must choose between distinct vision and binocular vision. Distinct vision is more craved for, and more useful, than binocular vision, especially if the latter be not quite perfect, owing to one eye being more defective than the other; consequently he sacrifices binocular vision, and squints. The dilemma ends, and asthenopia ceases.*

Conditions causing Hyperopia—1. *Axial Hyperopia.*—This is the commonest form, and is the condition of most eyes at birth. It is due to the shortening of the antero-posterior diameter of the eye, and may be due to a flattening of the globe or to a general diminution in size. Roughly, every 3 D of hyperopia represents a diminution of 1 mm. of the axial line.

This condition is due to an arrest of growth of the eye, and is often associated with arrest of growth of the neighbouring bony parts; thus, the face of a hyperope often shows want of relief.

The tendency is for hyperopic eyes, at birth, to grow towards the normal and even to become myopic; but after fifty, owing to the increase in size and the flattening of the lens with age, there is a tendency for all eyes to

* Donders called this form of hyperopia *relative*.

become hyperopic as life advances; this is called *Acquired Hyperopia* (see page 136).

2. *Curvature Hyperopia:* due to a lack of convexity of the refractive surfaces; it is generally associated with astigmatism (see page 112).

3. *Index Hyperopia:* due to diminution in the index of refraction of the media.

4. Hyperopia may be due to absence of the lens (*aphakia*), or its total or partial dislocation.

5. Tumours or exudations causing *advance of the retina* in the eye will cause hyperopia.

Symptoms.—It is the facultative hyperopia which the patient can correct, and thus more or less conceal at will, which is one of the most common causes of eyestrain, and the reason is very apparent.

In absolute Hm, vision is never acute, and the patient makes no attempt to strain his accommodation, because he finds the result of little or no use.

In relative Hm, we have seen that only monocular vision can be acute, and that asthenopia generally ceases when the squint appears.

Patients with facultative Hm are most frequently quite unaware that they are suffering from any defect of the eyes; they can see well at a distance, their near vision is as good as they want, they have no idea that the headaches that come on after near work, are caused by eyestrain, and they will in all probability be treated for all manner of diseases before the real cause is discovered. It is true that when this eyestrain lasts long, signs of inflammation will often show themselves in the eye and its appendages, such as conjunctivitis and blepharitis, and lead the patient to the eye surgeon, but even he may miss the true cause unless he make it a rule to examine, under atropine, the eyes of all young people suffering from chronic inflammation of the lids or conjunctiva, they being especially the subjects of this condition.

The facultative hyperopia of the young becomes after middle life absolute.

Although it is quite possible to suffer from facultative Hm, and pass through youth without any symptoms of eyestrain, sooner or later they will appear. Good health, plenty of outdoor exercise, and not too much application to books, will ward off eyestrain for a long time; but in these days of examinations, the day must surely come when the young student must "cram," when he must read four or five hours a day by artificial light, when he must do more work and take less play—in other words, when he must use his muscles of accommodation for a much longer time. And now, after a few hours' reading, his head aches, his eyes pain, and the type runs together. Of course, many such cases may occur from simple overwork in emmetropes, but I am confident that many a young man has broken down reading for his "Tripos," simply because he is hyperopic and has over-strained his eyes. I have known several men suffer from eyestrain for the first time through taking up German or Hebrew; the fine strokes that have to be recognised in order to distinguish the different letters (especially is this so in Hebrew) put an extra strain on the accommodation, and if the eye start with a deficit, as it does in hyperopia, eyestrain is sure to ensue.

If symptoms of eyestrain occur among the upper classes who suffer from this low form of hyperopia, how much more must they occur in those who spend their lives at close work, in badly lighted and badly ventilated rooms, with little or no outdoor exercise and often insufficient food. Yet the large army of seamstresses and compositors, who find their way to the out-patient room of an ophthalmic hospital, are, I believe, only a small fraction of the number who really want relief, but do not recognise it because they see well without glasses. Those who do come for advice generally tell the same

tale; they are at work, say, from eight in the morning till eight or ten at night, and towards evening they complain that their vision becomes less acute, and their eyes and head ache. It is but natural; their ciliary muscles have been working at high pressure all day, and in their little way have done as much work as the leg muscles would in a thirty-mile walk. Surely in an emmetropic eye we should expect fatigue under such circumstances; how much more, then, in a hyperopic eye!

With advancing years the latent hyperopia becomes gradually (and finally, about the age of forty, entirely) manifest, and with the diminution of accommodation range the hyperope necessarily becomes prematurely "presbyopic." As we should expect, symptoms of eyestrain are much more common in presbyopes who are hyperopic than in those who are emmetropic or myopic.

One of the results of *eyestrain* in young hyperopes, or in those who have to make great efforts to see small objects, as watchmakers, is **spasm of the ciliary muscle**, whereby vision is accommodated for near objects, and the patient rendered artificially myopic (see page 185). This spasm is usually accompanied by a contracted pupil from associated spasm of the sphincter of the iris, both conditions being caused by direct or indirect irritation of the third nerve.

Hyperopic headache is often accompanied by twitchings of the eyelids.

Besides the many symptoms of asthenopia already described, the special indications of hyperopia are—

1. Spasm of ciliary muscle, often producing apparent Myopia.

2. Sudden failure of the ciliary muscle from fatigue, causing obscurations of vision.

3. Convergent strabismus.

4. Apparent divergent Strabismus.

The angle gamma is larger—*i.e.*, the distance between

the macula and optic axis is increased, which causes the axis of the cornea to appear to diverge (see page 172).

There are also certain physical signs noticeable in hyperopes.

The eye is flatter than normal and often markedly smaller ; if the eyeball be turned strongly in or out, the equatorial region presents a much sharper curve than in the normal or myopic eye, showing its shortened axis.

The cornea is often smaller than normal. The face is sometimes flat-looking.

The ciliary muscle of a hyperope is always larger than normal ; this is specially marked in the annular muscle of Müller, and is due to excessive use.

The Diagnosis of Hyperopia by Examination—

(1) Vision is improved by, or is as good with, convex glasses.

(2) Retinoscopy gives a shadow moving " with " with a plane mirror, and a reverse shadow with a concave mirror, and the brighter the shadow and the quicker its movement, the lower the hyperopia.

(3) The indirect ophthalmoscopic examination shows an image of the disc larger than normal, and diminishing on withdrawing the lens from the eye.

(4) In the direct ophthalmoscope examination, if the observer's accommodation be relaxed, a convex glass is required in the ophthalmoscope to obtain a clear image of the fundus. If the hyperopia be high, the mirror alone, a short distance from the eye, shows an erect image of the fundus moving *with* the observer.

The Influence of Age on Hyperopia. See Presbyopia, page 136.

Treatment.—When the patient is under fifteen use atropine, whenever possible, to paralyze the ciliary muscle; and over fifteen and up to forty use homatropine ; over forty no mydriatic is necessary, and may even be dangerous, as at this age there may be a tendency to glaucoma,

which is especially determined in hyperopic eyes, because of their formation (a small, flat cornea and large ciliary muscle tending to block the filtration angle). By means of retinoscopy and testing before the type we ascertain the *atropine* correction of the defect. It is important to note that, in the subjective examination with the test types, the patient generally prefers a weaker lens than the objective examination indicated. This is sometimes caused by the correcting glass being further from the eye, and thereby increased in value. In low degrees of hyperopia this discrepancy is barely noticeable, but when high power lenses are used it is very marked.

We must bear in mind that, as the accommodation is never so relaxed as when it is under a cycloplegic, we must not order the *full* atropine correction. One good rule is to neutralize the whole of the Hm and $\frac{1}{4}$ of the Hl. Thus, a patient with Ht = 2.5, of which .5 is manifest, and consequently 2 latent, should have as glasses for constant wear + 1—*i.e.*, $.5 + \frac{1}{4} \times 2$.

As a matter of fact, the ideal treatment would be to correct the *whole* of the hyperopia, because we thus render our patient emmetropic and restore the harmony between the accommodation and convergence.

The correct treatment, I am sure, is to decide each case according to its own special requirements, the degree of hyperopia and the age of the patient being very important factors.

1. *In Patients under Twelve.*—Give the full correction less 1 when the H is of medium amount, say up to 4 or 5. The patient will very often at first complain of the glasses, but by their rigid use, taking care that they shall be circular, so that he cannot look over them, the eyes will soon conform to the altered conditions.

If the H be higher it is as well at first to take off from the atropine correction a little more than 1—viz., 1.5 or 2, but a greater deduction should not be made.

The correction of the Hyperopia, when adopted with those who have developed internal strabismus, has often the happiest results, for we may cure the squint without resorting to an operation, and the result is in direct ratio to the youth of the patients. Moreover, these are the hyperopes who can most readily be made practically "emmetropic," and therefore get the greatest gain from the glasses; for their very defect, the squint, shows that they have been unable to dissociate their accommodation and convergence. It is this habit of using their accommodation in excess which prevents many hyperopes from taking full correction. They cannot unlearn the habit, and naturally the older the patient the greater the probability is there of this being the case. In such cases we must commence with a much weaker convex glass, and we must hope to be able to increase it later.

When the amplitude of accommodation is great, the patient will probably prefer a weaker glass than we wish to give, and *vice versâ*. When the *hyperopia is slight*, *the vision good*, *no symptoms of strain present*, and there is *no* squint, *we should abstain from ordering any glass*.

2. *In Advanced Youth and Early Middle Age* it is unwise to follow any rule about the deduction for atropine, because the personal equation is a most important factor. Wait for the patient to recover from the cycloplegic, and then examine before the type, taking off the smallest amount that will just give distinct vision for distance. For instance, supposing 6 D represents the H. the patient may only tolerate 3, and .5 added produces blurring; therefore order +3, and in a few months, when the eye has adapted itself to the altered circumstances, you may be able to order +4. If you insist on the higher glass at first, the patient finds he cannot see so well with the glass as without it, and there is the danger that he will not use his correction.

Sometimes these patients will receive great benefit

from their partial correction when not using the eyes much for near vision, but will complain that they feel they want stronger glasses for near work; these you are always justified in ordering under the circumstances, and the strength may be up to the full atropine correction.

3. *In Later Life*, when the latent H has become manifest and absolute, two pairs of glasses are required, because the distant and near vision must both be corrected. For distant vision give the strongest glass the patient will accept, and for near vision ascertain the correct glass by the rules laid down on page 142.

To avoid the constant change of glasses, "Franklin" glasses are much to be recommended. The patient looks through the top of the glass for distance and the lower part for near work (see page 143). Or the patient may have his distant correction put into spectacles, and for reading he may place in front of these, pince-nez, or "hook fronts" (see page 143), to correct his presbyopia. If "Franklin" glasses are ordered the patient should be warned to lift the glasses when going up and down steps and stairs.

It is important to remember that hyperopia tends to decrease towards emmetropia. A child may be hyperopic to the extent of 2 D, and as the growth and development of the different parts of the body proceed, the flatness of the eye may disappear, and by puberty the eye may have become emmetropic. For this reason it is necessary to re-examine the eyes of children almost every second year, in order to make sure they are not wearing too strong a convex glass, which would induce an artificial myopia, which in turn might lead to real myopia. This tendency for the eye to grow normal is often interfered with by the presence of asthenopia; hence one of the benefits derived from glasses in young children is the increased chance of the eye improving and growing to the normal shape, and the possibility of discontinuing the use of spectacles.

CHAPTER VIII.

MYOPIA.

Myopia (*μύειν*, to close, *ὤψ*, the eye, from the habit of myopes to partially shut the eyes in order to lessen the circles of diffusion), or short-sight, is a condition of the eye in which the retina is situated behind the principal focus (Fig. 15, M), and only divergent rays from a near point (Fig. 47) or parallel rays made divergent by a concave glass (Fig. 48), can come to a focus on the retina.

The retina of a myopic eye is the conjugate focus of

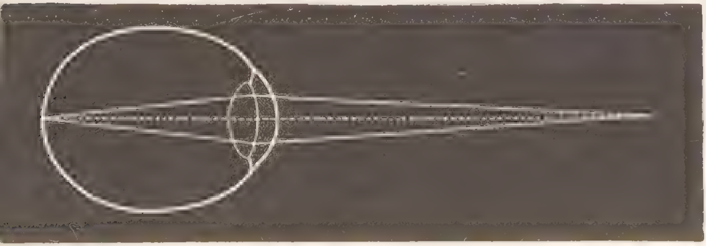


FIG. 47.

an object situated in front of the eye at a finite distance, or, in other words, the punctum remotum of a myope is always at a finite distance, the distance being measured by the amount of myopia. Thus, a myope of 1 has his far point 1 metre from the eye, a myope of 2 has his far point $\frac{1}{2}$ metre, or 50 cms., and a myope of 5, 20 cms. from the eye.

A myopic eye sees distinctly at infinite distance (when

accommodation is relaxed) with that concave glass whose focal length is equal to the distance of the far point from the eye, and the converse is true: the measurement of myopia is that concave glass with which the myopic eye sees distinctly objects at infinite distance, and its focal length is equal to the distance of the myope's far point from the eye. If the accommodation be relaxed the strongest concave glass is the measure of the myopia.

We can ascertain the punctum remotum of a myope directly by measuring the farthest distance at which he can see objects distinctly; thus, if such a spot be 2 metres from the eye, this is R, and its expression in dioptres is r = $\frac{1}{2}$ or .5, hence the myopia = - .5.

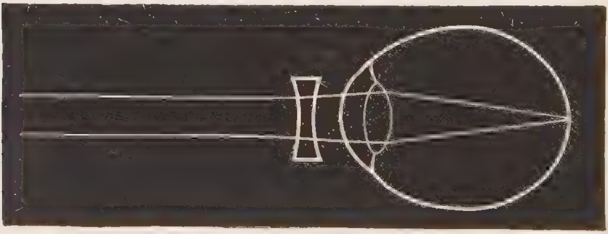


FIG. 48.

The condition of myopia of the eye may come about in the following ways:

1. By elongation of the axis of the eye—**axial myopia.** This may be due to—

(*a*) General elongation of the eye—**typical myopia.**

(*b*) Localized protrusion of the sclerotic, particularly at the posterior pole—**staphyloma.**

2. By increase of the refractive power of the eye—**refractive myopia.**

This may be due to—

(*a*) Increase in curvature of the cornea, as in myopic astigmatism.

(*b*) Increase in the curvature of the lens—

(*α*) In spasm of the accommodation.

(*β*) In luxation of the lens.

(*c*) Increase of the density of the lens, as at the beginning of senile cataract.

3. A combination of 1 and 2, as in **conical cornea,** when elongation of the axis and increase in the curvature of the cornea coexist.

Thus, we see that typical myopia is due to an elongation of the antero-posterior diameter of the eye, and (roughly speaking) every dioptre of myopia represents a lengthening of this axis by about $\frac{1}{3}$ of a millimetre.

The punctum remotum and punctum proximum of a myope are ascertained according to the methods already given.

The punctum proximum is nearer the eye than in emmetropia, and the higher the myopia the nearer it is.

As r has a positive value in myopia, the amplitude of accommodation is the difference between p and r; thus $a = p - r$.

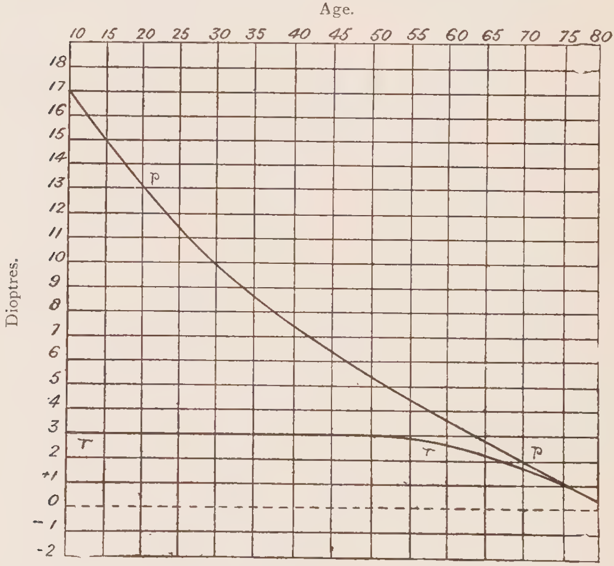
The diagram (Fig. 49) represents the amplitude of accommodation of a myope of 3 D at the different ages. The line p begins at the figure 17, showing that at the age of 10 the near point is 6 cms. from the eye; therefore $a = \frac{100}{6} - 3 = 17 - 3 = 14$ D. At 30 years of age $p =$ 10 D, and P is 10 cms., while R is still 33 cms. on the positive side, $a = 10 - 3 = 7$ D.

At the age of 55 r begins to curve downwards, and reaches the zero line at 80, so that at this age the myope of 3 has lost all his myopia; p and r unite (showing that all accommodation is lost) at the age of 75.

The Influence of Age on a Myope.—At the age of 45, when the emmetrope becomes presbyopic, the myope of 3 D can bring his work as near as 16 cms. to his eye, for p crosses the 45 line at 6.5, and it is not till he reaches the age of 55 that his near point has

receded to 22 cms., the point that Donders marked as the commencement of presbyopia.

The Relation between Accommodation and Convergence.—A myope of 5 D can see a point 20 cms. from the eye without using his accommodation, but he must converge to 5 m.a. in order to see binocularly. As



Showing the range of accommodation of an uncorrected myope of 3 D at different ages.

FIG. 49.

a compensation for the visual defect, most myopes have the power of using their convergence in excess of their accommodation, just as a hyperope has often the power of using his accommodation in excess of his convergence; but, as we have seen (page 84), they both have to pay a penalty for this, the liability to strain always being greater when either effort is used in excess of the other. The

"fusion supplement" must be greater than in emmetropia, and *the greater the "fusion supplement" the greater the fatigue to the internal recti;* the fatigue leads to "insufficiency" of the muscles, and matters are made worse. But it is not only the *excess* of convergence, but the *excessive* convergence that tends to produce strain and fatigue of the internal recti. The uncorrected myope sees nothing distinctly beyond his far point, and when he wishes to see clearly he must bring everything within that point; for instance, an emmetrope wishes to know the time by the clock, he can see the clock across a room, but the myope must go up to the clock and bring it within his far point; and, moreover, the incentive to use this remedy is great because the remedy is perfect. A high hyperope has the same difficulty with distant objects, but he has not the same remedy. Naturally, the greater the myopia, the nearer is the far point, and the greater is the convergence strain.

A myope requires more convergence of the visual lines because vision takes place closer to the eyes, and, as Donders has shown, precisely in myopia is this for two reasons more difficult—first on account of impeded movements due to the altered shape of the eyeball, which becomes ellipsoidal in form, and which, in turning round the short axis in a cavity of similar shape, gives rise to great resistance; and, secondly, on account of the altered direction of the visual lines, the angle γ (angle formed by the visual and optic axes) being smaller than in emmetropia or hyperopia (see page 172). If a myope cannot dissociate his accommodation and convergence, he has the same difficulties as a hyperope: he can either see distinctly, but sacrifice binocular vision to remove the diplopia, or he can use his accommodation when he does not require it, and see indistinctly.

From the observations of Donders, Nagel, and Landolt, we find that the relative amplitude of accom-

modation and convergence (see page 51) vary considerably, not only according to the refractive error, but also in different individuals with the same error. There is a tendency for the accommodation to adapt itself to the altered state of refraction, hence most myopes can converge in excess of their accommodation; and when the myopia increases, the excess of convergence over accommodation also increases.

The Causes of Myopia.—Although myopia is hereditary, it is, with few exceptions, not congenital. We have seen that almost all eyes are hyperopic at birth.

The savage is rarely myopic: it is civilization that is responsible for it. The necessity for constantly adapting the eye for near objects means undue convergence.

We find that myopia generally first shows itself at the age of 8 to 10, when school work begins in earnest—that is, when convergence is first used in excess—and there is no doubt that excessive convergence is mostly responsible for the development of myopia. The overused internal recti constantly pulling at the sclerotic tend to lengthen the antero-posterior diameter of the eye, becoming then a very potent factor in the causation of myopia, and as this lengthening of the antero-posterior axis necessitates greater convergence still, a vicious circle is produced, and the myopia tends to increase.

The hereditary character of myopia is explained by the existence in such eyes of an "anatomical predisposition" to myopia. The sclera is unusually thin, and consequently less able to resist the pull of the internal recti, and the relative position of the recti and the position of the optic nerve, both of which may be hereditary, may be factors in the production of this defect.

Anything which causes young subjects to approach their work too near the eyes may be the starting-point of myopia. Bad illumination, or the light coming from the wrong direction (for instance, in front) or defective vision

produced by corneal nebulæ, or lamellar cataract, etc., all necessitate over-convergence in order to obtain clearer images, and myopia may be produced.

One of the strongest examples ever shown to prove that undue convergence causes myopia, is that of the divinity students in Germany, almost all of whom are myopic.

It is interesting to note that when the work is approached very near the eye, but convergence is not used, as in the case of watchmakers, who habitually use a strong convex glass in one eye, there is no special tendency to myopia.

Symptoms and Diagnosis of Myopia.—(1) Distant objects are seen indistinctly, because parallel rays focus in front of the retina and cross and form diffusion circles on the retina, and the higher the myopia the larger the diffusion circles; these are reduced, commonly, by the myope "screwing up" his eyes, and in later life by the contraction of the pupils.

(2) Near objects are seen distinctly, and the near point is much nearer than in normal eyes.

(3) Acuteness of vision is often lowered, and in high myopia this is invariably the case, because the stretching of the eye leads to atrophic changes in the retina and choroid.

(4) The presence of convergence insufficiency and latent divergence (diagnosed by the Maddox test, page 42) for distant and near objects, often becoming manifest later, and ending in divergent strabismus.

(5) An apparent convergent strabismus due to the angle γ being negative (page 171).

(6) Most of the symptoms of asthenopia, but not so frequent or so marked as in hyperopia (see Muscular Asthenopia (page 153).

(7) Spasm of the ciliary muscle, which apparently increases the amount of myopia, so that young subjects will choose a stronger concave glass than they require.

(8) A prominence of the eyeball is sometimes noted in high myopes, but is not always present. A dilated pupil and dreamy stare are sometimes present.

(9) Muscæ volitantes are often complained of. These are probably due to the indistinct vision allowing the vitreous to be seen against a hazy background.

(10) In high myopia vitreous opacities are sometimes numerous and most annoying.

(11) Myopes often stoop very much and become "round shouldered" from their habit of poring over their work, and this stooping at near work tends to produce congestion of the eyes and appendages.

It should be noted that, in low degrees of myopia, often the only symptom present is indistinct distant vision, and this, very often, is not recognised by the patient as a defect. Such people learn to recognise indistinct outlines by the aid of other senses in a way that emmetropes can hardly understand, and when, in later life, they can put off the wearing of glasses for near work for many years, or till extreme old age, what wonder that they and their relations imagine them to be possessors of remarkably good sight!

The Diagnosis of Myopia by Examination.

Objective Examination.—*The Ophthalmoscope:* (1) *The Indirect Method.*—By this method the disc appears smaller than in emmetropia. On withdrawing the focussing glass from the patient's eye the disc becomes larger. Without the focussing glass, in high myopia the fundus is seen very large and inverted, if the observer be not nearer the aerial image than his own near point. The image of the disc moves in a direction opposite to that of the observer's head.

(2) *The Direct Method.*—By this method—viz., with the ophthalmoscope close to the eye—the fundus is

indistinct, and concave glasses have to be rotated in front of the opening; the weakest concave glass that gives a distinct image is the measure of the myopia, if the observer's accommodation be relaxed.

Retinoscopy.—With a plane mirror the shadow moves "against" and with a concave mirror, "with," if the observer be beyond the patient's far point. With the observer seated one metre from the patient, the measure of myopia of a meridian is that concave lens which gives the point of reversal, with 1 D added (see page 73).

Subjective Examination.—Having ascertained the amount of error by the above methods, we seat the patient before the test types, and proceed to correct with concave lenses in the trial frame.

Remember that as the correcting glass may be further from the eye than the glass used during retinoscopy, and as concave glasses lose in power by removal from the eye, we may want a stronger lens than the objective examination indicated. (The discrepancy increases with the higher defect.) Thus, if retinoscopy at a metre from the patient gives us the point of reversal with -5, we call the amount of defect -6, and before the types the patient may prefer -6.5 or -7.

Note the weakest lens that gives the most distinct vision with each eye separately, and then try the glasses binocularly when binocular vision exists, as sometimes the patient will accept and prefer a slightly weaker glass.

As the circles of diffusion are removed by correction, the myope often finds that concave glasses reduce the size of objects.

Changes in the Fundus in Myopia.—In most myopes a white crescent is observable on the temporal side of the disc; this is the myopic crescent; it may not be limited to this part, and may even surround the disc (see frontispiece). In high myopia it often spreads on the outer side towards the macula. It is very often limited

by a ring of pigment. This crescent, which is a localized atrophy of the choroid, is brought about by the stretching of the tunics in the formation of the posterior bulging or staphyloma posticum of the eyeball, and by the tilting of the disc. The "dragged disc" is due to the resistance of the optic nerve (often shorter than normal) on the one side and the posterior staphyloma on the other. Whether the atrophy is secondary to choroiditis or merely due to insufficient nutrition, it is difficult to say, but it is probably the former. Von Graefe asserted that the staphyloma posticum is due to a sclerotico-choroiditis. If this be so, then this particular spot bulges, because it is unsupported by the recti which compress the sides of the globe. This also explains why undue convergence, by increasing the intra-ocular pressure by pressing the recti on the globe, is such an important factor in causing and increasing myopia. The dragged or tilted disc is very characteristic, and becomes deeply cupped in some cases. This cupping is quite distinct from glaucomatous cupping, in that it is most marked on the nasal side, the vessels rising up and dipping down over the tilted edge in a very characteristic fashion, and it does not occupy the whole area of the disc (see frontispiece).

If the myopia progress, choroiditis may become general, accompanied by cyclitis, and after a time white patches of choroidal atrophy, with masses of black pigment forming their boundary, are scattered all over the fundus. The inflammation extends to the vitreous, causing liquefaction of that body and subsequent shrinking, and the consequent loss of support to the retina may end in detachment of that membrane. Unfortunately, very often some of the most serious changes occur at the macula, as this is the region of the bulging, and hæmorrhages and consequent atrophy lead to a result as disastrous as the detachment.

Such cases of high myopia have been termed "malig-

nant," and it is very probable that many of them ought not to be classed under myopia at all, but that the myopia is only a symptom of a disease attacking the eye.

The milder cases of progressive or malignant myopia (wrongly so called) are often the result of wrong treatment, as we shall see later.

Treatment.—As in hyperopia, I divide the patients into three classes:

1. *Early Youth.*—Under no circumstances attempt to estimate the refraction in young children without atropine. Having estimated the full error, order the full correction, and never give weaker glasses, and do this whatever the amount of myopia, giving the strictest instructions that the glasses must be worn always.

Following out the idea of reducing convergence strain to a minimum, the most rigid attention should be paid to ophthalmic hygiene. The schoolroom should be lofty and large, and have large high windows on one wall. The seats and desks should be arranged in rows, so that the pupils sit with the windows on their left. It is impossible, of course, to suit each pupil with seat and desk, but as most children of the same age are of the same height while sitting, and in the same class, the height of the desk from the seat should increase gradually with the classes, the highest class having the highest desks. Priestley Smith has devised a "hygienic desk" and a table of the different sizes to suit all requirements; this table he has adapted and altered from one suggested by Snellen.

If we have a uniform sized seat and desk for the whole school (which often happens), the youngest pupils are too near their work, and the oldest are too far away and have to stoop. When sitting at the desk, which should have a slight slope, the height of the seat should be such that the student can keep almost erect, and yet write comfortably at the same time.

School-books should be printed in a good type, un-

cramped. The printing of this book may be taken as a very fair sample of what the type of school-books should be. Of course, the books for very young children must be printed in larger type.

And last, but not least, let us beware of overtaxing the child's brain, and, as almost a necessary consequence, the eyesight as well. Day says: "The weakening more and more of the overtaxed brain lays the foundation of nerve exhaustion, and disorders are induced which years may never overcome," and he specially remarks on the harm done by teachers and parents by pushing a precocious child. The school work that needs close application of the eyes should be continued only for a short period at a time, the periods alternating with other work, which does not require the use of the eyes, such as mental arithmetic or recitation, and play.

Schoolmasters should *teach* more—that is, they should explain and impart knowledge by demonstrations and simple lectures—and reduce as much as possible the time spent in "home preparation," which is usually work done by bad light, and when the student is physically and mentally tired.

2. *From Puberty to Adult Age* (25 or 30).—Homatropine may be substituted for atropine as a cycloplegic, and whenever possible the error should be estimated under its effect.

When the effect of the cycloplegic passes off, the patient may prefer $-.5$ or even -1 added to the atropine correction, and if the improvement with this addition is marked, give it, but on no account add more, and order the glasses to be worn always.

By fully correcting the myopia we restore the harmony between the accommodation and convergence efforts, but for this very reason, although the treatment is almost always practicable in young people, older patients refuse it. The habit of converging in excess of their accommodation has

become so fixed in some patients that it cannot, even by practice, be disturbed, and if we insist on this correction for near work, we *create strain* instead of removing it. As a matter of fact, distance glasses for these patients need be the sole treatment when the myopia does not exceed, say, 5 D. We must remember that there are many persons with a myopia of 3 D who never use glasses all their life; they put up with the indistinct distant images, and learn to recognise them, and their near work need not be near enough to cause any convergence strain.

It is most important, in giving concave glasses for near work, to insist on the work being held at a good distance, not nearer than 33 cms. from the eyes, otherwise we not only fail to remove the convergence strain, but render the patient liable to accommodation strain, for the myope's ciliary muscle is weaker, and therefore more liable to fatigue than that of an emmetrope or hyperope.

If the myope will not bear the full correction for near work, we order glasses two, or at the most three, dioptres weaker, with the advice that he should use them only when settling down to near work; but on all other occasions he should use his long-distance glasses, and try and gradually become accustomed to them for near work. The older the patient and the higher his myopia, the more difficult will be this treatment, for his accommodation has been so long idle that the ciliary muscle is too small and weak to do its proper work.

If the patient be a student, or engaged in literary or other work which entails close application for many hours a day, and if he be free to regulate his work, we should advise working for shorter periods and with longer intervals of rest than he has been accustomed to, by daylight working with the window at his side, preferably the left, and at night using a lamp (which throws a good even white light on his work) so shaded that no light from the lamp reaches the eyes directly.

3. *About* 30 *and over.*—Homatropine only, need be used, and in many cases it may be omitted. When the patient has never had his proper correction he will at this age never learn to read with his distance glasses, hence he must always have two pairs.

All the more will this be the case when he arrives at 40 or 45, the emmetrope's presbyopic period; we must then reduce the concave glass by the amount we should, in the emmetrope, put up as a convex glass.

The best way is to treat each case according to its requirements, and not bind ourselves to a rigid rule, but carefully test the patient, find out his working near point, and keep more accommodation in reserve than we should in the emmetrope, because the muscle is weaker.

In many cases of *very high myopia*, when the patient has not been accustomed to wear correcting glasses, it will be useless to try and give the full correction even for distance, and we must then take off as little as possible, and test binocularly, when he has binocular vision. For instance, he may have -20 in R.E., and -18 in L.E.; perhaps binocularly he prefers -18 and -17; if so, these may be ordered (see Anisometropia, page 144). In high myopia we have often to take off more than 3 for near work.

Remember that the ideal treatment of all myopes is a full correction of the error, because we thereby lessen convergence, train the ciliary muscle to work, and prevent the progressive character of the defect. I am quite convinced that *progressive myopia in a large percentage of cases means under-corrected myopia.* The older oculists were afraid to give full correction.

In many cases of high myopia when the fundus changes are recent, it is wise to place the eyes under atropine for a long period in order to ensure complete rest, give tinted glasses, and advise the patient to go into the country, and spend his time as much as possible

out of doors. In all young subjects this should be insisted upon.

The Treatment of High Myopia by Discission and Removal of the Lens.—When the patient is not older than 25, the myopia very high, vision very poor, and not improved by glasses beyond $\frac{6}{24}$, and when the fundus changes are not very marked, and especially when the myopia is progressive, the lens may be removed by discission. The improvement is sometimes very great, the patient being able to see better, without a glass, than he did previously with a strong concave lens. (For details of this treatment the reader should consult a text-book on ophthalmology.)

CHAPTER IX.

ASTIGMATISM.

Up to the present, in discussing errors of refraction, we have seen that both hyperopia and myopia are mainly due to an alteration in shape of the eye as a whole, the antero-posterior axis being too short or two long---axial ametropia; but the fact was also mentioned that alterations in the curvature of the cornea or lens would produce these errors, that if the curvature were too flat parallel rays would focus beyond the retina, and if too sharp, in front of the retina. It is these errors of curvature that we shall be dealing with now.

In the normal standard eye, if an opaque disc with a slit aperture (Fig. 50) be placed in front of it, at whatever angle this slit is rotated, distant objects will be seen through it distinctly—that is, parallel rays will focus on the retina—and in simple hyperopia and myopia the same result is obtained after correcting the ametropia with a spherical lens, because the surfaces of the dioptric apparatus are perfect spheres, and consequently all the meridians have the same curvature. But suppose we take an eye in which the vertical meridian is normal—*i.e.*, parallel rays passing through this meridian focus on the retina—but in which the horizontal meridian has a flatter curvature, then parallel rays passing through this flatter curvature will focus beyond the retina, and as they impinge on the retina will form diffusion circles. In such a case all the meridians, between the horizontal and vertical, will have a different focussing point, such point

gradually approaching the retina as the meridian becomes more vertical.

Such an eye is astigmatic, and **astigmatism may be defined as an ametropia of curvature**, a condition in which rays of light, passing through the dioptric apparatus, do not focus at a single point.

In *regular* astigmatism, of which the above is an example and which we shall now be dealing with, the meridians of greatest and least curvature are always at right angles to each other, and are called the principal meridians; the meridians in between have a greater or less curvature, according as they are nearer

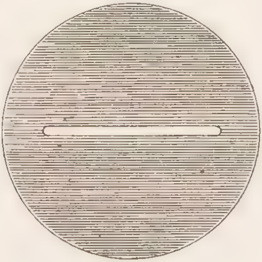


FIG. 50.

to the former or to the latter. The meridian exactly between the two (corresponding to an angle of 45° if the meridians of greatest and least curvature are vertical and horizontal) has its focussing point exactly between the focussing point of the greatest and least curvature.

The bowl of a spoon is an exaggerated example of an astigmatic surface, the curve from side to side being much sharper than that from the handle to the tip of the spoon.

Fig. 51 shows the kind of images formed by a regular astigmatic surface. Let the vertical meridian have a curvature A B, so that parallel rays passing through it focus at *f*. Let the horizontal meridian C D have a flatter curvature, so that rays passing through it

are focussed beyond f at f'. (For the sake of simplicity we ignore all the remaining meridians.)

At f the vertical rays have come to a focus, and therefore form a point of light; but the horizontal rays have not come to a focus, and will be spread out, as at (2), into a horizontal line, called the anterior linear focus. The reverse obtains at f', as shown at (4), because the horizontal rays have come to a focus, and the vertical have crossed and form diffusion circles, and spread out the points of light into a vertical line called the posterior linear focus. At (1) none of the rays have focussed, but

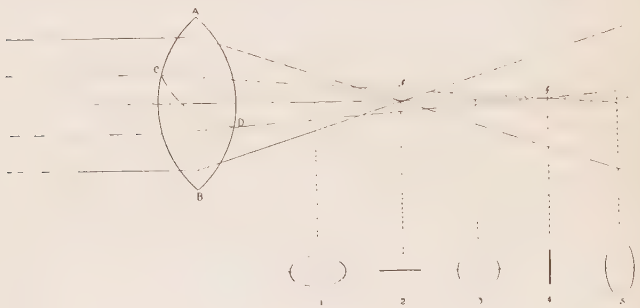


FIG. 51.

the vertical are nearer the focus than the horizontal, so the figure here will be a horizontal ellipse. At (3) the vertical rays, having crossed, are diverging as much as the horizontal are converging, and here the figure is a circle. At (5) the vertical rays are more out of focus than the horizontal, so that we have a vertical ellipse.

When the retina is situated at any of these positions (1-5), the image on the retina will be something like the diagrammatic sketch. The interval between f and f'—*i.e.*, between the focal points of the principal meridians—is called the "focal interval of Sturm," and represents the amount of astigmatism.

It is important to remember that the vision of an astigmatic person is different from that of the ametrope; objects may not appear blurred generally, but perhaps only in parts; lines are lengthened or broadened, and circles appear elliptical. He may be able to read some letter in $\frac{6}{6}$, but even in line $\frac{6}{18}$ he may not read all correctly; he supplies the visual deficiency by guessing.

In every eye affected with regular astigmatism there is one direction in which straight lines appear most distinct, and another at right angles to it in which the line is most indistinct; hence, if two lines at right angles to each other are held before an astigmatic eye, they

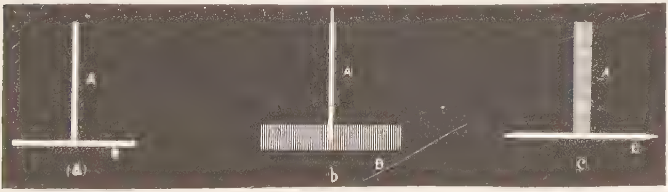


FIG. 52.

cannot both be distinct: if one is in focus, the other is blurred.

In the example above, where the vertical meridian is more sharply curved than the horizontal, at the anterior linear focus (f) a horizontal line will appear in focus, but a vertical line blurred; and at the post-linear focus (f') a vertical line will appear in focus and a horizontal line blurred; they cannot both be in focus at the same time.

Thus, when two lines at right angles to each other (A and B, Fig. 52, *a*) are looked at by an eye affected with simple astigmatism, if the *vertical* meridian be defective, A will appear defined and B blurred, because A is spread out vertically, and this does not affect the definition,

while the vertical "spreading out" of B makes the line appear blurred (Fig. 52, *b*). If the horizontal meridian be defective, the reverse happens (Fig. 52, *c*).

In all probability the eye does not accommodate for either of the foci, but, by accommodation, tries to get an image of the object as nearly circular as possible, as at (Fig. 51 [3]), and, as we shall see later, this very accommodation is one of the causes of astigmatic asthenopia.

Varieties of Regular Astigmatism (Fig. 53):

Variety of Astigmatism.	Refraction of the Principal Meridians.	Position of the Principal Focus.
1. Hyperopic Astigmatism—		
(*a*) Simple.	Emmetropic.	On the retina.
	Hyperopic.	Behind the retina.
(*b*) Compound.	Both hyperopic.	Both behind the retina, one being nearer than the other.
2. Myopic Astigmatism—		
(*a*) Simple.	Emmetropic.	On the retina.
	Myopic.	In front of the retina
(*b*) Compound.	Both myopic.	Both in front of the retina, one nearer than the other.
3. Mixed Astigmatism.	Hyperopic.	Behind the retina.
	Myopic.	In front of the retina.

Generally, the vertical meridian, or one near it, is most convex, and this is called "astigmatism according to the rule." Thus, in regular astigmatism the horizontal meridian (or one near it) is hyperopic in simple and mixed astigmatism and most hyperopic in compound hyperopic astigmatism, and the vertical meridian (or one near it) is myopic in simple and mixed astigmatism and most myopic in compound myopic astigmatism. In Fig. 53 all the examples show astigmatism "according to the rule." If the conditions are reversed, it is called "astigmatism against the rule." When the meridians are exactly oblique—*i.e.*, at an angle of 45° or

135°—by some this is called "oblique astigmatism," by others it is reckoned as "according to the rule."

Symmetric Astigmatism is when the axis of the principal meridian in each eye is identical; for instance, the

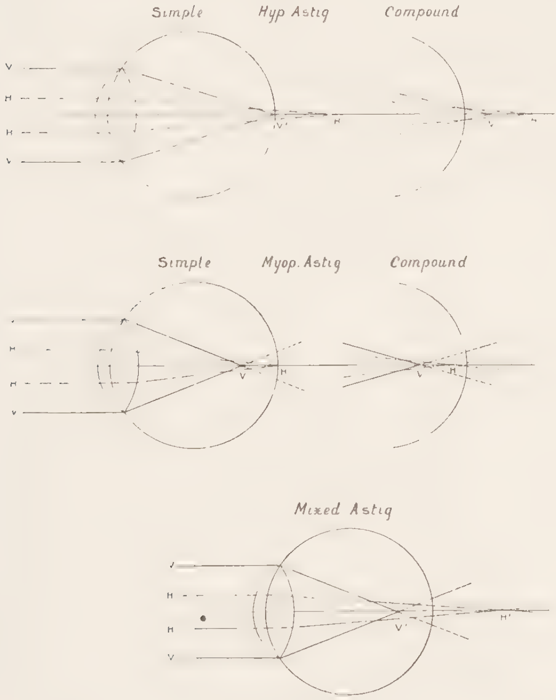


FIG. 53.

V, Rays passing through the vertical meridian.
H, rays passing through the horizontal meridian.

meridian of greatest curvature is vertical in both eyes, or is 15° from the vertical passing down and in, in both eyes; and *Asymmetric Astigmatism* is the reverse.

Homonymous Astigmatism is when the axes of the

principal meridians in each eye are more or less parallel; for instance, the axis of the correcting cylinder passes down and *in* 15° from the vertical in the right eye, and 10°, 15°, or 20° down and *out* in the left eye.

The Seat of Astigmatism.—In regular astigmatism the seat is chiefly in the cornea, due (1) to congenital malformation of the cornea, often traced to heredity; or (2) to acquired alteration in the curves of the cornea, produced by operations, such as iridectomy and operations for cataract, or inflammation of the cornea; or (3) to pressure from tumours in the lid.

Transient astigmatism can be produced by pressure on the eye with the finger, or by contraction of the lids or the extra-ocular muscles. Congenital corneal astigmatism is, more or less, stationary through life; acquired astigmatism of the cornea alters, and very often is considerably reduced by time.

Even in the normal eye there is a certain amount of astigmatism, because the cornea is not a perfect sphere, but an "ellipsoid of revolution" (see Fig. 73); but this "physiological" astigmatism is so small that it can, in most cases, be ignored.

The *lens* may also be the seat of astigmatism, which may be "static" or "dynamic."

The static crystalline astigmatism is generally small in amount, and, being in the same meridian, adds itself to that of the cornea, thus increasing the total astigmatism of the eye; but sometimes the crystalline astigmatism is the reverse of that of the cornea, and so corrects it.

Dynamic Crystalline Astigmatism is nearly always corrective, and is the inverse of that of the cornea. It is produced by an unequal contraction of the ciliary muscle, and is a most potent factor in astigmatic asthenopia.

Symptoms of Astigmatism.—When the astigmatism is pronounced, acuteness of vision is below the normal. Spherical glasses may improve the distant sight to a cer-

tain extent, but the correction is never complete. On directing the patient to look with one eye at Snellen's "Fan" (Fig. 54), placed 5 or 6 metres off, or nearer if necessary, we find that he can see certain lines more distinctly than others. The vertical lines may be seen quite black and distinct, the horizontal lines being faint, or *vice versâ* ; or the oblique lines on one side may be distinct, those on the other side at right angles to the former, being indistinct. If all the radiating lines are indistinct, we must make one of the meridians emmetropic, by placing before the eye the weakest concave or strongest convex spherical glass that is required to make one set of lines distinct and black.

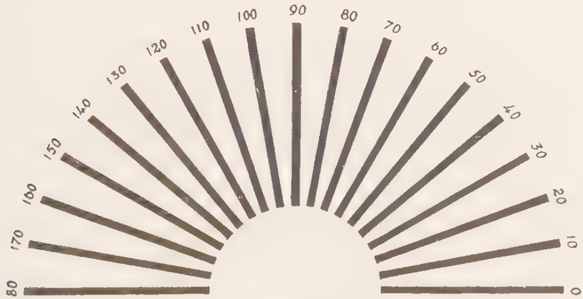


FIG. 54.

As we have already seen, when rays coming from a point are refracted at an astigmatic surface, a linear image of the point is formed at the focus of each principal meridian, and the direction of the linear image *is at right angles* to the meridian at whose focus it is formed. Thus, when a patient sees the horizontal lines distinctly, and the lines as they pass to the vertical become less distinct, reaching the maximum of indistinctness in the vertical lines, we know that the *vertical meridian* is emmetropic, or nearly so. Such a patient would complain that the letters of the test type were spread out horizontally,

and if we place before the eye a stenopaic disc with the slit vertical, we shall find all his symptoms of astigmatism disappear. He sees all the lines with equal clearness, and the letters appear normal, because the vertical slit has cut off all the horizontal rays that caused the blurring.

Astigmatic Headache.—The commonest symptom is asthenopia, and of all the forms of asthenopia, **headache**. In fact, one can say that eyestrain is caused by astigmatism in more than 75 per cent. of the cases, and that headache in young people is more often due to astigmatism than to any other cause.

Hyperopic astigmatism is the commonest form, and mixed astigmatism is the rarest. The causes of eyestrain in astigmatism are:

1. *The Confusion of the Images.*—This has already been referred to on page 112. The eye, as a rule, does not accommodate for either the anterior or posterior linear focus, but for a point between, where the image is approximately a circle. This leads to a frequently varying accommodation effort, which sooner or later must end in fatigue, because not only is the ciliary muscle being used when it ought to be at rest (when looking at distant objects), but it is impossible to always maintain this accommodation for this point, and we get confusion of images.

This confusion is worse in hyperopic astigmatism. We have seen that the curvature of the vertical meridian is always the greatest in astigmatism "according to the rule," hence the letters are spread out laterally, and the words appear very confused; we can prove this for ourselves by holding up before one eye (the other being closed) a concave cylinder of, say, 1.5 D, with its axis vertical: if we turn the axis round to the horizontal, making ourselves vertically hyperopic, the letters are spread out vertically, and the words are very much clearer.

2. *Meridional Asymmetrical Accommodation.*—Unequal contraction of the ciliary muscle, producing an astigmatism of the lens the inverse of that of the cornea, and more or less correcting it.

With few exceptions the seat of regular astigmatism is in the cornea, due to a difference in the curvature of the different meridians; added to this there is sometimes found a "static crystalline astigmatism," due to a difference in the curvature of the different meridians of the lens, and the two together make up the total astigmatism of the eye which is revealed under an ordinary examination. But most frequently, although astigmatism of the eye is suspected, where it is of low degree it may be impossible to detect it without resorting to a cycloplegic. Donders in 1864 first drew attention to this, and he pointed out that the corneal astigmatism was masked and corrected by an *inverse astigmatism of the lens;* Dobrowolsky in 1868 asserted that this crystalline astigmatism was produced by an *unequal contraction of the ciliary muscle;* and Hensen and Voelckers later, have shown by experiments upon animals that this unequal contraction is possible. They showed that when a filament of the ciliary nerve was divided, the portion of the muscle supplied by it was relaxed, and that on stimulating the cut end a local contraction took place.

But, in addition to this physiological proof, the clinical proofs are even more conclusive.

Let us take a typical case. A patient complains of headache accentuated by near work. Examination reveals no refractive error. The ciliary muscle is paralyzed, and astigmatism is discovered. This is corrected by cylinders, the glasses are ordered to be worn always, and in a short time the headache disappears.

Again, very often when the effect of the cycloplegic has passed off, the patient refuses the cylinder that improved his vision under atropine. He tells you that it

makes his vision worse. In spite of this you prescribe it, and—this is a very important point—you insist on the glasses being worn always. He returns in a month or two, assuring you that his headache has entirely disappeared, that he has become accustomed to the glasses, but that he cannot now see as well without them, as he could before using them.

What has happened? At first, when the effect of the atropine has passed off, the ciliary muscle returns to its old habit of unequal contraction, and consequently the correcting glasses, instead of helping, make matters worse; but by constantly wearing them the necessity for this unequal contraction disappears, the muscle resumes the normal condition and allows the glasses to do the work. Vision is apparently worse without the glasses, because the muscle has forgotten its bad habit; but, of course, like all bad habits, it can be easily re-acquired. The patient has lost nothing but his headache. What stronger proofs could we have that this unequal contraction does occur?

Further, as lenticular astigmatism must necessarily be very small it can only neutralize a low degree of astigmatism in the cornea, and it is just in these cases where headache is most frequent.

It is easy to understand how this unequal contraction of the ciliary muscle causes discomfort or pain, especially in a neurotic subject. It may be also that several causes are present, such as constipation, worry, etc., and that this form of eyestrain is the "last straw on the camel's back." Sometimes it is only towards middle age, when the ciliary muscle is losing its vigour, that the strain shows itself.

This unequal contraction of the ciliary muscle must interfere with the nutrition of the lens, and I believe it is a very potent factor in the causation of cataract.

In high astigmatism there may be some asymmetry of the face, but otherwise there are no physical appearances

that indicate astigmatism. In oblique astigmatism the patient may acquire the habit of holding the head on one side, but this is not always the case; on the other hand, if a patient, in reading the distant types, does hold the head obliquely, we may be almost certain that oblique astigmatism is present.

Diagnosis and Measurement of Astigmatism.—There are numerous methods for detecting and measuring astigmatism, and they may be ranged under two heads:

(*a*) *Objective Methods.*—1. By the shadow test, or retinoscopy (see page 69).

The patient being, if possible, under the influence of a cycloplegic, the refraction of the different meridians is estimated in the manner described on page 73. When all the meridians have the same refraction, there is no astigmatism; when there is a difference, astigmatism is present, and its degree is estimated by the difference between the meridian of least and the meridian of greatest refraction. The axis of the correcting cylinder will be in the same direction as that of the meridian of least refraction (see Shadow-test, page 74). For instance, supposing we find the vertical meridian shows a hyperopia of 1.5 and the horizontal a hyperopia of 2.5, then the astigmatism equals 1 and the axis of the convex cylinder is vertical. Or, again, using a concave mirror, supposing we find the shadow moves "against" in the direction 15° from the vertical down and in and a + 2 corrects, and the meridian at right angles gives a shadow "with" corrected by − 1, we have mixed astigmatism amounting to 3 D and corrected by a concave cylinder − 3 placed 15° from the vertical down and in and a + 2 sphere, or a convex cylinder + 3 with its axis 15° from horizontal down and out and a − 1 sphere.

Retinoscopy is a very valuable help in estimating astigmatism; it is accurate and simple, but is not so delicate as the ophthalmometer.

2. *The Ophthalmometer.*—This instrument only estimates the corneal astigmatism, and not the total astig-

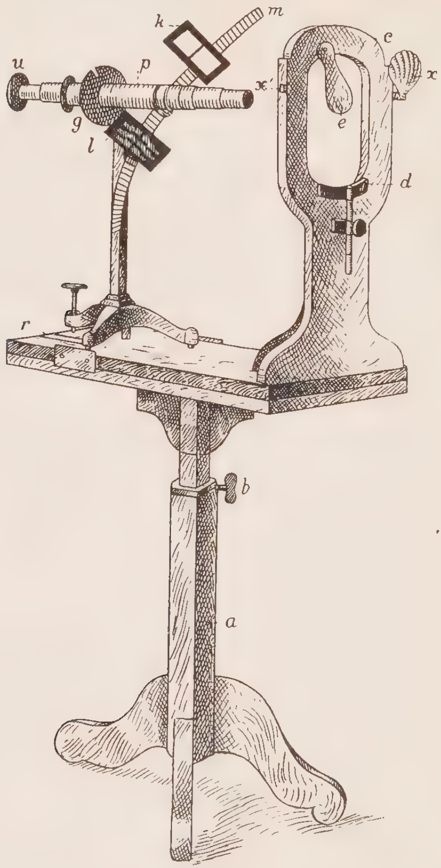


FIG. 55.*

matism of the eye; but as the lenticular astigmatism is, as a rule, dynamic and corrective, it can be ignored.

* In the above illustration the light and the reflector on one side (x') have been removed.

The simplest form is that made by Kagenaar of Utrecht from Javal's model, and may be briefly described (Fig. 55).

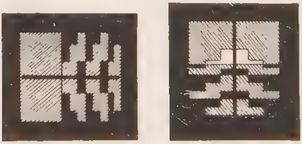
The essential parts of the instrument are two mires *k* and *l*, whose image is reflected on the cornea of the patient, and seen by the observer through a telescope *u*, containing a Wollaston prism between two bi-convex lenses. The patient's chin rests on *d*, and his forehead should press against the top of the stand at *c*, and the eye not being examined is covered by the movable clip *e*. The mires are carried on a graduated arc *m*, which can be rotated into any position, and at *g* there is a graduated disc, which by means of a pointer shows the meridian of the arc *m*. The mire *k* is fixed, but the mire with steps *l* can slide along the arc; these two mires are illuminated best by electric lamps, fixed (with reflectors) on the stand, on both sides of the patient's head (*x* and *x*′), or, better, by making the mires of ground glass and placing small electric lamps behind them. When electricity is not available gas or lamps must be used, as ordinary daylight is insufficient.

Seated on the other side of the stand the surgeon looks through the eyepiece *u*, and points the telescope to the eye, and by means of the screw at *r* moves it up or down until he sees four figures on the patient's cornea, which are two reflections of each of the mires. Ignoring the outside figures, he now accurately focusses the two inside ones by moving the telescope on its stand nearer to, or further from, the patient.

The first step is to ascertain the axis of the astigmatism, when present, and we start with the arc *m* horizontal, and note whether in the reflection of the two mires the deep black line which runs through the centre is a continuous black line running through both; if not, the arc must be revolved to the right or left (but never more than 45°) until this result is obtained; we then read off

the axis on the dial. The next step is to move the mire l (with the steps) along the arc, until its reflection is just in contact with the reflection of k, as in Fig. 56, *a*. This, then, is the primary position of the ophthalmometer—viz., with the central black lines of the two mires forming an unbroken black line and the two inner edges of the mires just in contact.

We now revolve the arc through a complete right angle, and if the relative position of the reflection of the mires has not changed, then there is no corneal astigmatism; but if, with the arc vertical, or nearly so, the reflections overlap (as in Fig. 56, *b*), there is astigmatism "according to the rule," each step of the reflected mire



a *b*

FIG. 56.

overlapping representing one dioptre of astigmatism; or we note the exact position of mire l on the graduated arc in the primary position, and, after turning the arc into the secondary position, move the mire l till its reflection is again just in contact with the reflection of k, and read off on the arc the secondary position; the difference between the two represents the astigmatism.

If, on revolving the arc from the horizontal to the vertical position, the reflections separate, we are dealing with astigmatism "against the rule," and we must then make the secondary position our primary position, and proceed as before. It is important to remember that this instrument only gives the astigmatism of the cornea; there may be some *static* lenticular astigmatism, hence

glasses should never be prescribed from the ophthalmometer examination alone.

There is only one objection to the ophthalmometer, and that is its expense.* If used as a servant, and not allowed to become master, it is one of the most valuable adjuncts to the ophthalmologist's consulting-room, for after some months' practice, and when all the tricks of the instrument are learnt, in about one minute the observer ascertains (1) whether astigmatism is present, (2) the amount, and (3) the direction of the axis of the principal meridian; and, moreover, this is done with such delicacy that $\frac{1}{8}$ of a dioptre of astigmatism is revealed.

In the telescope, at the observer's end, is a crossed "spider thread," which must be focussed by means of the eye-piece at *a* (Fig. 55) before the examination begins.

In low degrees, probably owing to some static astigmatism of the lens, there is generally about .25 of astigmatism "against the rule," which must be added to the ophthalmometric astigmatism. Thus, when the ophthalmometer shows *no* astigmatism, there is .25 "against the rule"; when it shows astigmatism "according to the rule," there is .25 less; and when it shows astigmatism "against the rule," there is generally about .25 more.

3. *The Ophthalmoscope.*—Ophthalmoscopically, astigmatism is revealed by observing that all parts of the fundus are not in focus at the same time, no matter what lens we turn into position.

Estimation of the Amount of Astigmatism by the Ophthalmoscope.—Bearing in mind the fact that vertical vessels are seen through the horizontal meridian, and horizontal vessels through the vertical meridian, we focus, for instance, the vessels passing horizontally from the disc to the macula, and find the weakest concave or strongest convex glass that gives us the best picture; this will, of course, give us the refraction of the meridian at right angles to this—viz., the vertical. We then focus the

* From £12 to £16.

vessels that pass up or down from the disc, and estimate thus the refraction of the horizontal meridian, and the difference between the two meridians is the measure of astigmatism.

When the principal meridians are not horizontal and vertical, we focus vessels passing obliquely, say up and out from the disc, and afterwards those passing down and out, and so on.

The patient must be under a cycloplegic and the observer's accommodation must be relaxed, which introduces the personal element and causes this method to be rarely used by ophthalmologists in preference to retinoscopy or the ophthalmometer.

It is important to remember that the vessels to be observed should be those situated near the macula, because we are estimating the refraction of the central part of the dioptric system.

The Ophthalmoscope by the Indirect Method.—This is of little use in diagnosing astigmatism, except in high astigmatism. When the focussing glass is withdrawn from the eye, if the aerial image remain the same size in one meridian, but become smaller in the other, the case is one of simple hyperopic astigmatism, and if the image become larger it is a case of simple myopic astigmatism. In compound hyperopic astigmatism the image becomes smaller in both meridians, but more so in one, and the reverse, of course, in compound myopic astigmatism.

(*b*) *Subjective Methods.*—1. Methods based on the fact that when astigmatism is present, lines running in different directions are not all clearly seen at the same time—

Brudenell Carter's clock.
Snellen's fan or "rising sun."
"Confusion letters" such as E and Z.
Pray's letters.

Carter's Clock (Fig. 57) and *Snellen's Fan* (Fig. 54), if

observed by a non-astigmatic eye, will be seen to have the lines all equally black; but in astigmatism the vertical lines, for instance, will appear black while the horizontal are gray, or the oblique down and in black, and the oblique down and out, gray.

It should be borne in mind that the meridian of the eye which corresponds to the darkest lines is the meridian

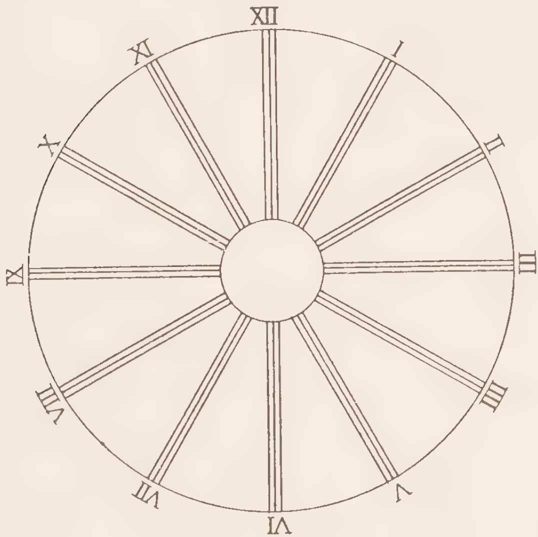


FIG. 57.

of greatest ametropia; thus, a patient who requires – 1, axis horizontal, to make all the lines appear equally dark, has simple myopic astigmatism "according to the rule," and sees the horizontal lines darkest before correction. The patient's eyes must be under a cycloplegic, and concave or convex spherical glasses may have to be placed in front of the eye to correct any general ametropia present, otherwise the whole chart may be out of focus.

This method is not delicate enough for very low degrees of astigmatism, and, in fact, is rarely used now.

Confusion Letters.—There are certain letters which astigmatics often confuse, such as D and O or U, E and Z, S and B, and when a patient on using Snellen's types makes these mistakes we suspect astigmatism.

Pray's Letters are letters printed with stripes running in different directions; the patient selects the letters that appear darker than the other, and the direction of the stripes in the selected letter or letters corresponds to the meridian of greatest ametropia (Fig. 58).

2. **The Chromo-aberration or Cobalt-blue Test,** based on the principle that violet or blue rays, being more refrangible than red, are brought to a focus sooner (Chromatic Aberration).

Cobalt-blue glass contains a great deal of red, and allows only blue and red rays to pass. Such a glass of suitable thickness is mounted in a trial frame placed before the eye to be examined, the other eye being excluded. A clear round point of light should be looked at from a distance of 4 to 6 metres. When the eye is emmetropic, the light appears violet; when hyperopic, the light appears blue in the centre surrounded by a red ring; and when myopic, red in the centre surrounded by a blue ring. If astigmatism be present the light appears oblong, vertically, or horizontally, in different characteristic shapes. Scientifically, this is a most interesting test, but its weakness consists in the fact that it is purely subjective, and that the surgeon is entirely dependent on the patient's description.

3. **Examination of the Patient before Snellen's Types**—(*a*) *With the Stenopaic Slit* (Fig. 51).—This is an opaque disc to fit into the trial frame, and through the centre there is a slit about 1 millimetre broad. On looking through this slit the patient sees only rays passing through the meridian corresponding to the slit;

all other rays are excluded, and the glass in front of this slit that gives the best vision represents the refraction of this meridian. The slit is then turned round at right angles, and the refraction of the other meridian is taken. The difference between the two meridians is the

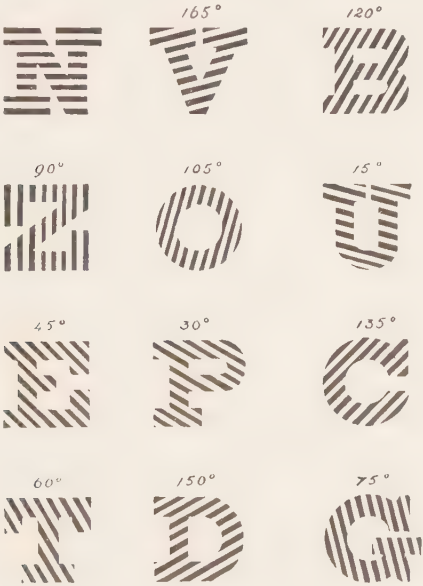


FIG. 58.

amount of astigmatism, and the value of the cylinder that will have to be employed to correct the defect.

For instance, when, with the slit vertical, $\frac{6}{6}$ is read, and convex glasses make vision worse, this meridian is emmetropic. On turning the slit round, when a + 1 glass is required to get $\frac{6}{6}$, this meridian is hyperopic, the astigmatism is 1 D, and is corrected by a cylinder + 1 axis vertical.

This method is not very accurate, as much depends

on the width of the slit, and better and quicker methods have superseded it, but sometimes in a difficult case of mixed astigmatism it is of some assistance.

(*b*) *With Cylinders.*—This method is too wearisome to be used by itself, but when we have ascertained the refraction by the ophthalmometer and retinoscopy, we always employ it as a final test.

Treatment.—The estimation of astigmatism is now ascertained entirely by (1) the ophthalmometer, (2) the shadow test, and (3) the final trial of glasses before Snellen's types placed at 6 metres from the patient.

Regular astigmatism is corrected by cylindrical lenses.

Armed with the knowledge of the refraction of the principal meridians and the direction of the axes, this final testing is very easy. The difference between the two meridians represents the strength of the cylinder, and the spherical glass is represented by the refraction of the weakest meridian; thus, when the horizontal meridian is -4, and the vertical -6, we take a cylinder -2, place its axis to correspond with the least ametropic meridian—that is, horizontal—and combine it with a spherical glass -4.

In *Mixed Astigmatism* the selection of the glasses is a little more complicated. As before, the difference in refraction of the two meridians equals the amount of astigmatism. Supposing the horizontal is $+3$, and the vertical -2, 5 D is the amount of the astigmatism. Now, we can use either a concave cylinder and convex sphere, or *vice versâ*, and sometimes it is as well to try both kinds, as one may be preferred. The common practice is to use concave cylinders and convex spheres, because, when the patient recovers from the atropine, the convex sphere may have to be reduced, and this is better than adding to the concave sphere. In this case, then, we take a -5 cylinder and place it in the trial frame, with its axis at right angles to the myopic meridian—

i.e., horizontal—and then we correct the hyperopia by placing up a +3 spherical. The rule in mixed astigmatism is: the cylinder is the difference between the two meridians, and its axis is at right angles to the meridian whose sign it corresponds to, and the spherical glass is the value of the meridian whose sign is the opposite of the cylinder.

In the above example we might have ordered +5 cylinder axis vertical, and −2 spherical, and many prefer this method, as it gives a periscopic effect (see page 11). *Never* in such a case order *two* cylinders—that is, do not prescribe the above as +3 cylinder axis vertical ⁐ −2 cylinder axis horizontal, as the optician must be most careful to grind the cylinders exactly at right angles to each other, and in cutting down the glass to place it in the frame it is very difficult to insure absolute accuracy. If by any chance the glasses are worn askew, both axes will be wrong, whereas in the proper method with *one* cylinder, only one meridian will be affected.

We may have to add or subtract from the various glasses, sphericals or cylindricals, to get the best result, and the axis of the cylinder may be some degrees out from what we expected, for it should always be turned round slowly in order to find the best position ; but if we have done our retinoscopy correctly, the alterations before the type are inconsiderable. Remember that our objective examination is our guide and servant : it must never be our "master." The subjective examination must always *have the last word*.

As in hyperopia and myopia, the treatment varies with the age of the patient and also with the individual.

1. *Early Youth.*—When the astigmatism is under 1 D, and there are no symptoms of astigmatic asthenopia, such as headache, and the correction makes little or no difference to the visual acuity, do not give a cylinder, but

correct with sphere only, if required. In hyperopia, especially when strabismus is present, and the glasses have to be worn always, it is important the child should not look over the glasses, and therefore they ought to be made circular. If you put a cylinder into a circular glass the axis may shift and thus do harm.

On the other hand, if headache, or blepharitis, or constantly recurring attacks of phlyctenular conjunctivitis, or corneal ulcers, or troublesome winking, etc., are present, correct fully, and order the glasses to be worn in the shape of large ovals.

2. *In Youth or Early Middle Life.*—Correct fully always, and deal with the spherical glass as indicated in discussing hyperopia and myopia. The only exception is in high myopia. Unless the astigmatism be high—say over 2 D—don't correct it when the cylinder does not improve vision, because it is important that the glass should be ground concave on both sides; for when a cylinder is given, unless you can obtain a toric lens (see page 11), the whole of the myopia must be corrected on one side, and a very heavy, awkward glass is the result.

3. *In Later Life.*—When astigmatism has never been corrected and when it is high, the patient may be unable to stand the full correction; so you may have to give a weaker cylinder.

Again, in later life, when a cylinder has never been worn and no symptom exists, and when the astigmatism is low, it may be advisable not to correct it.

With the above exceptions, never alter the cylinder or its axis after having ascertained both under a cycloplegic.

In ordering cylinders be careful to indicate accurately the axis. If you do this by simply writing down the degrees, a mistake may occur, as there is no uniformity at present in the numbering of the trial frames or prescription forms. Indicate the axis in degrees from the

vertical or horizontal as in Fig. 59, or on an optician's form, or, better still, on a form engraved or stamped on your paper as in Fig. 60.

Irregular Astigmatism. — Physiological irregular astigmatism is present in all lenses. It is due to separate sections of the lens having a different refractive power,

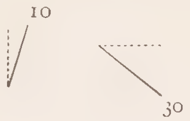


FIG. 59

and is infinitesimal in amount. It is this condition which causes a bright star to appear as a radiating figure instead of a bright point.

Sometimes the refractive power of the separate sections of the lens is so great that several images of a point are formed, and it is in this way we get monocular polyopia in incipient cataract.

Irregular Astigmatism in the Cornea may be considerable,

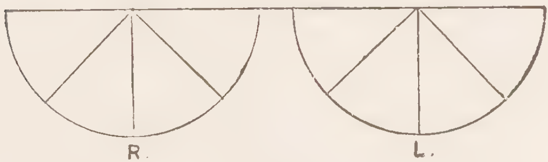


FIG. 60.

and is generally the result of disease, such as ulcers, nebulæ, wounds, and conical cornea. It is due to a difference in curvature in different parts of the same meridian, and often produces distortion of objects, which regular astigmatism rarely does.

Irregular Astigmatism may be Diagnosed by : (1) *Placido's*

Disc (Fig. 61).—This is a round disc supported by a handle. The disc is about 7 or 8 inches in diameter, and has painted on one side alternate concentric rings of black and white, and has a small hole in the centre. The patient stands with his back to the light, and the disc is held by the surgeon a short distance from the patient's eye in such a manner that an image of the rings is

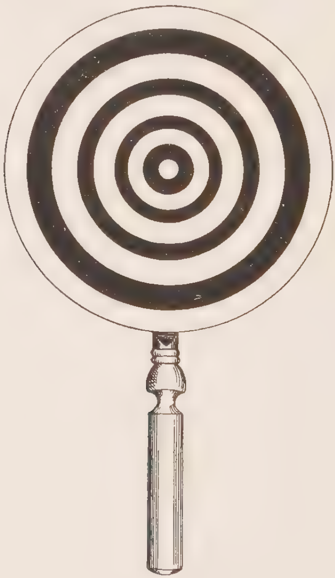


FIG. 61.

thrown on to the cornea to be examined, the patient being directed to look at the centre. Looking through the central hole, the surgeon sees a diminutive image of the rings on the cornea, and if the latter is normal the rings are round and evenly separated. In regular astigmatism the image appears elliptical, the long axis corresponding with the meridian of least curvature; but when

irregular astigmatism is present, the rings are "crinkled" and distorted.

2. *The Ophthalmometer.*—The reflection of one or both mires is distorted, and this distortion and the relative positions of the mires vary irregularly in different positions of the arc.

3. *Retinoscopy.*—There is no definite shadow, or if it be present, it behaves in an irregular manner, and glasses produce no definite and regular effect.

Treatment.—Place before the eye in a trial frame an opaque disc with a small central hole (stenopaic disc), shift the position of the stenopaic opening, and also place up different lenses. If vision be improved, order these *stenopaic spectacles*, with or without the lens or combination of lenses; and if the best position of the stenopaic opening be *not* central, indicate how much it must be decentred. In some cases, especially in conical cornea, considerable improvement results from this treatment, for we cut off the peripheral rays passing through the more distorted parts of the cornea and lessen the confusion. Unfortunately, in most cases the spectacle treatment of irregular astigmatism is useless.

NOTE.—In the choice of a cycloplegic in estimating regular and irregular astigmatism, be guided by the remarks on pages 89, 103, and 183.

CHAPTER X.

PRESBYOPIA.

The Influence of Age upon the Accommodation—*Presbyopia*.—The amplitude of accommodation diminishes with age.

At the age of 10 years the average **emmetrope's** near point is 7 cms. from the eye, and his far point being at infinity, we see that his amplitude of accommodation is 14 D (in Fig. 62, in the first column on the left, there are 14 divisions between p and r), whereas at the age of 30 his near point has receded to 14 cms., and his amplitude of accommodation is then only 7 D—that is, in twenty years he has lost half of his accommodative power.

The same happens whatever the refractive condition of the eye. For instance, a **hyperope** of 4 D (Fig. 63) at the age of 10 has his near point 10 cms. from the eye, and $p = \frac{1 \text{ metre}}{P} = \frac{100}{10} = 10$ D, r is negative, and

$$\begin{aligned} a &= 10 - (-4) \\ &= 10 + 4 \\ &= 14 \text{ D} \end{aligned}$$

Again, at 30 we see (Fig. 63) that $p = 3$ D, P being now 33 cms. from the eye, and

$$\begin{aligned} a &= 3 + 4 \\ &= 7 \text{ D} \end{aligned}$$

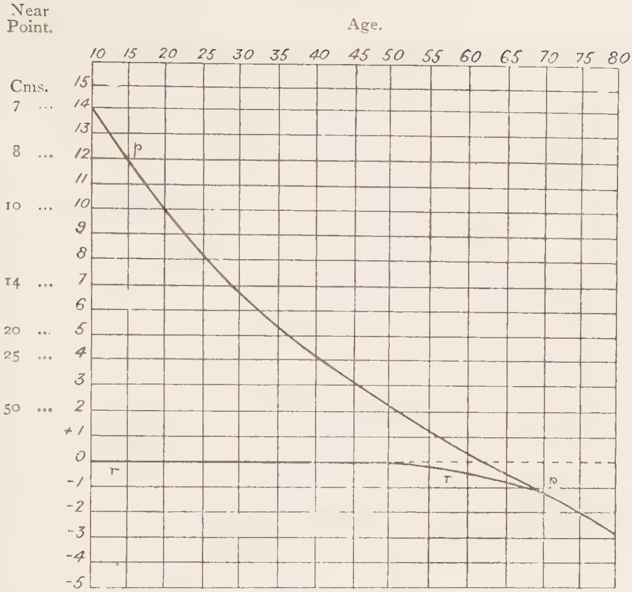


FIG. 62.*

Showing the range of accommodation of an Emmetrope at different ages.

A **myope**, say, of 3 D (Fig. 64) has his near point, at the age of 10, 6 cms. from the eye, and p = 17 D

$$\begin{aligned} a &= 17 - 3 \\ &= 14 \text{ D} \end{aligned}$$

At the age of 30 we see by the diagram that p = 10 D, for P = 10 cms., and R is still 33 cms. on the positive side; hence

$$\begin{aligned} a &= p - r \\ &= 10 - 3 \\ &= 7 \text{ D} \end{aligned}$$

* The numerals above represents years, those on the left, dioptres The line p p represents the curve of the punctum proximum, and the line r r that of the punctum remotum.

Whatever the static refraction of the eye, *r* remains stationary till about the age of 55, when we see that in all three diagrams it begins to curve downwards, showing that the emmetrope becomes hyperopic, the hyperope more so, and the myope less so. This is called *acquired hyperopia*. A point is finally reached when *p* and *r* unite—in other words, when all accommodation ceases; this is about the age of 75; but in emmetropia and

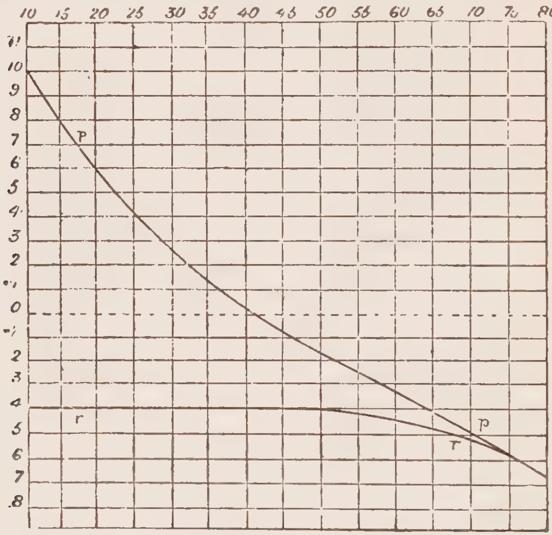


FIG. 63.*

Showing the range of accommodation of an uncorrected hyperope of 4 D at different ages.

hyperopia the positive part of accommodation—viz., that employed for near objects—ceases at an earlier age. In emmetropia *p* is seen to cross the zero line between the ages of 60 and 65 (Fig. 62) (some accommodation is

* The numerals above represent years, those on the left, dioptres. The line *p p* represents the curve of the punctum proximum, and the line *r r* that of the punctum remotum.

still left, but it is employed in correcting the "acquired hyperopia"), and in hyperopia even earlier. The greater the degree of hyperopia, the earlier will *p* cross the zero line. In the case of a hyperope of 4 D (Fig. 63) this happens between the ages of 40 and 45—that is, a hyperope of 4 D, when he reaches the age of 42, although he has some amplitude of accommodation, has to make

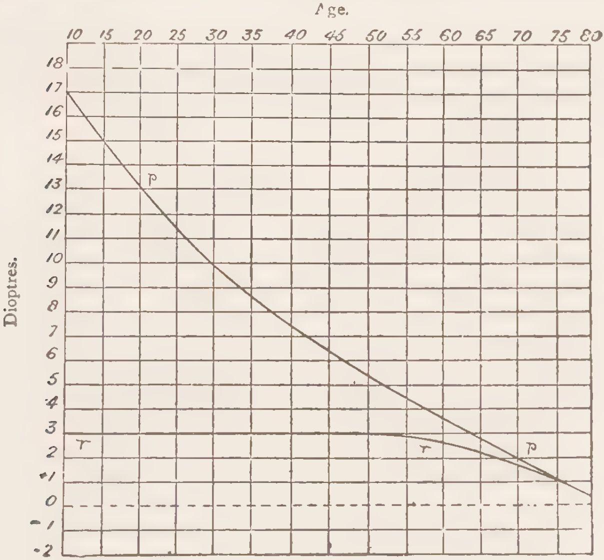


FIG. 64.

Showing the range of accommodation of an uncorrected myope of 3 D at different ages.

use of it entirely for distance; on the other hand, all myopes of more then 3 D can make use of all their accommodative power for near work (Fig. 64). These conclusions were arrived at by Donders from a number of observations made and recorded, and the diagrams are the results of the averages of these observations.

By referring to Fig. 62 we get the following table:

Every person ought to have at

Age.	Range of Accommodation.
10	14 dioptres.
15	12 ,,
20	10 ,,
25	8.5 ,,
30	7 ,,
35	5·5 ,,
40	4·5 ,,
45	3·5 ,,
50	2.5 ,,
55	1·75 ,,
60	1 dioptre.
65	·75 ,,
70	.25 ,,
75	0 ,,

It is very important to remember that this table is meant to show only the average standard. In practice we often find considerable variation from it.

This loss of accommodative power in the eye is due to diminished elasticity of the lens; in other words, the greatest convexity the lens can assume is at the age of 10, and every year afterwards this convexity (which is the result of the fullest action of the ciliary muscle) becomes less and less, till a time arrives when it has lost all power of altering in shape. This loss of elasticity is accompanied by greater firmness of the lens, and in later years, by a loss of homogeneousness and transparency both of the lens and vitreous which is such a striking condition in youth. The lens reflects more light, and by oblique illumination often gives a false idea of cataract. At the age of 40, every individual has, more or less, about 4·5 D range of accommodation (see table). From our formula $a = p - r$ we get $p = a + r$—*i.e.*, $p = 4{\cdot}5 + r$. When the person is an emmetrope we can ignore r, therefore $p = 4{\cdot}5$. Now P, the punctum proximum, is $\frac{1 \text{ metre}}{p}$ therefore $P = \frac{1 \text{ metre}}{4\cdot5} = 22$ cms. That is, an emmetrope at the age of

40 cannot read nearer than 22 cms. or 9 inches. This is the point at which Donders has fixed presbyopia. At what age will a myope of 2 D have his near point removed to 22 cms.?

$$\begin{aligned} a &= \text{p} - \text{r} \\ &= 4.5 - 2 \\ &= 2.5 \end{aligned}$$

By our table we see that when the amplitude of accommodation has diminished to 2.5, the person's age is 50. Hence a myope of 2 D becomes presbyopic ten years later than an emmetrope. If the amount of myopia had been 4.5 D, *a* would have been *o*, and our table shows us that the age when all accommodation is lost is 75. The myope who all his life has never seen clearly without glasses beyond a point 9 inches from his eyes, has this solitary compensation, that he will be able to read without glasses up to and beyond the natural term of life.

As we have seen, a hyperope becomes presbyopic earlier than an emmetrope or myope.

At what age will a hyperope of 4 D become presbyopic—that is, have his near point removed to 22 cms.?

$$\begin{aligned} \text{a} &= \text{p} - (-\text{r}) \\ &= \text{p} + \text{r} \\ &= 4.5 + 4 \\ &= 8.5 \end{aligned}$$

Our table shows us that a person having an amplitude of accommodation of 8.5 D is 25 years old. It seems rather cruel to tell a young lady of 25, who is hyperopic to the extent of 4 D, that she is just commencing to suffer from "old sight," although it may be somewhat soothing to inform her that everyone really begins to suffer from it at the early age of 10.

Some writers object to the term "presbyopia," and would expunge it from ophthalmology, giving us nothing in its place. We must have some term to express that

condition in which, as the result of the increase of years, the range of accommodation is diminished and the vision of near objects is interfered with. But it certainly seems rather arbitrary to say that presbyopia commences when P has receded to 22 cms. from the eye; this can do no harm, if we bear in mind the fact that the presence of presbyopia does not necessarily entail the use of glasses for near work. A long-armed man will not thank you if you force him to bring his near work so close to his eyes.

The recognition of presbyopia is not difficult. When a person complains that he has to hold his book, when reading, further away than he has been accustomed to, that this is more especially so by artificial light, that the figures 3, 5, and 8 become confused, and that *n* and *u* are difficult to distinguish, and at the same time asserts that his distant vision has not altered, we may be almost certain we have before us a presbyope.

When a person whose near point has receded, say, to 33 cms. attempts to read or work at that distance for any length of time, symptoms of eyestrain will be sure to supervene. It is a fact that we get from everyday experience, that the full power of a muscle can be exercised only for a very short time without fatigue. A person whose near point is at 33 cms. is using the whole power of his ciliary muscle in order to focus an object at that distance on his retina, and fatigue of the muscle will very soon ensue. This fatigue causes the muscle to relax, it cannot contract to its full extent; vision then becomes hazy, and becomes distinct again only when the object has been further removed from the eye. At the same time the patient will probably complain that, after reading some little time, headache comes on, and the eyes begin to water; these temporary symptoms of eyestrain will pass into chronic symptoms in time, and the red, irritable-looking, watery eyes of middle-aged people are often due to this cause.

There is no doubt that presbyopia is a very fertile cause of eyestrain. I find, on referring to my own cases, that no less than 38·9 per cent. of presbyopes suffered from *accommodative asthenopia.*

Women at the climacteric—that is, about the age of 45 —often suffer from headache, and as this is commonly the age of presbyopia, it is possible that many "climacteric" headaches are the result of eyestrain, through the presbyope overtaxing her weakened accommodative power. Again, although the headache may not be actually caused by the eyestrain, the latter may start an attack in one predisposed.

The pupil diminishes in size with age, and the presbyope often increases this contraction by placing the lamp between the book he is reading and his eyes. The contraction of the pupils lessens or removes the diffusion circles.

Treatment of Presbyopia.—Two classes of patients come to us for treatment: one class simply request glasses for reading (some of these have been to various opticians and have not been suited, and we very often find them suffering from incipient cataract); the other class come complaining of some symptom of asthenopia, and they may or may not be aware that they require glasses.

A cycloplegic is not necessary (except in isolated cases where our results are unsatisfactory, and we wish to thoroughly examine the lens for cataract), ciliary spasm is very unlikely to be present, and latent hyperopia, when present, is becoming, or has become, manifest. We thus avoid the danger of glaucoma, which has sometimes been traced to the employment of atropine at this age.

We first test the patient's distant vision, and then find his near point of distinct vision, and also ascertain from him his usual or most comfortable distance for reading or working at. Suppose his distant vision is normal, and his punctum proximum in 28 cms., and the distance he

wishes to read at is 33 cms., he complains, we will say, of symptoms of eyestrain: how can we relieve him? His amplitude of accommodation is $\frac{100}{28} = 3.5$ D. Now, to avoid fatigue, he must not use the whole of this, but must keep about $\frac{1}{3}$ in reserve. Let him have 1.5 D in reserve; this leaves him 2 D available accommodative power, but to work at 33 cms. he requires 3 D. We supply this deficit by giving him + 1 D glasses to work with. He suffered from eyestrain because he was using almost the whole of his accommodative power.

The treatment, simple as it appears, is not always successful, because the amount of reserve accommodation left is not always large enough. It necessarily varies with the individual. When the ciliary muscle is weak, we must leave a larger reserve, and *vice versâ*. Most people put off "taking to spectacles" as long as possible because it is considered a sign of *old* age (ladies especially are very great delinquents in this respect), and when, after suffering eyestrain for years, they are forced to find relief in glasses, they seek the advice of an optician instead of an ophthalmic surgeon.

Persons should remember that convex glasses, even if worn before they seem to be necessary, can never do anything like the harm that eyestrain does.

We generally find in practice that an emmetrope of 45 requires a convex glass of 1 D, and an additional + 1 for every five years. If any error of refraction be present, that must be ascertained; the patient should then be supplied with the correcting glasses, thus making him more or less emmetropic, and the rest of the examination should be proceeded with as before, the convex glass that his presbyopia requires being added to the correcting glasses.

Thus, if the patient be hyperopic to the extent of 3, and we find by our examination that he requires an additional 1 to work with, we order + 4 for near work. If he

be myopic to the extent of 1, and requires an additional + 2 to read with, we add the negative glass to this, and give him + 1 for near work; and so with astigmatism.

When astigmatism is present, and the presbyope has never worn the correction, he may prefer to omit the cylinders; but if there are definite symptoms of strain it is wise to prescribe them, but at the same time to bear in mind that the treatment is more or less experimental.

If glasses have to be worn for distance and for reading, it is very convenient to have them combined in one spectacle, as in Fig. 65.

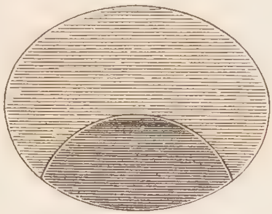


FIG. 65.

These are called **Franklin** or **pantoscopic spectacles.** The upper part of the glass corrects the distant vision, and the lower part near vision. They may be ground as two separate glasses, or the reading part may be cemented on with balsam. These are specially useful to persons who have to be alternately looking at distant and near objects (see page 92).*

When patients decline to have their "distant correction," and when their symptoms appear to be directly attributable to improperly-corrected presbyopia, reading glasses only may be prescribed, but with the understanding that, should symptoms of eyestrain continue, they must return for "distant" glasses.

* The additional glass required for reading may be made as a separate spectacle without sides, and arranged to hook on to the front of the other glasses; these are called "hook fronts."

CHAPTER XI.

ANISOMETROPIA.

Anisometropia is a condition in which the refraction of the two eyes is different. A difference in refraction in the two eyes is more often met with than absolute equality, and in astigmatism it is very common to find a difference of .25 or .50 between them; but in actual practice we recognise anisometropia to exist only when, to produce the maximum of visual acuity in the two eyes, different glasses are required.

Every possible combination may exist:

1. One eye may be emmetropic.
2. Both eyes may be ametropic—

    (*a*) The same variety of ametropia, but unequal in degree;

    (*b*) Different varieties of ametropia, one eye myopic and the other hyperopic; this variety is sometimes called antimetropia.

When one eye is astigmatic and the other hyperopic or myopic, the astigmatic eye has generally the same form of ametropia as the non-astigmatic eye, and very often one of its meridians has the same amount of ametropia.

Except when it is the consequence of an operation, loss of lens, etc., anisometropia may be regarded as congenital, and attributable to the unequal development of the eyes.

The difference in the refraction of the two eyes may be very great, and is then often associated with marked asymmetry of the face; a difference of 10 dioptres has been recorded.

Varieties of Anisometropia.—There are three varieties of anisometropia:

1. Simultaneous binocular vision exists.
2. The eyes are used alternately.
3. One of the eyes is permanently excluded.

1. SIMULTANEOUS BINOCULAR VISION.—*Tests for Binocular Vision.*—(*a*) *The Prism Test.*—The patient fixes an object at a distance, and a strong prism, base in or out, is placed before one eye, the other being uncovered; at the moment of interposing the prism, if the eye make a movement towards the apex of the prism, binocular vision exists.

(*b*) *Snellen's Coloured Glasses.*—This apparatus consists of a frame, hung up before the window, in which letters of coloured glass, alternately green and red, are placed. The patient standing in front of them, at 4 or 5 metres' distance, is provided with a spectacle frame into which one red and one green glass is placed, the colour of these glasses being of the same intensity as that of the letters. Only the red letters can be seen through the red glass and the green letters through the green glass, so that each eye separately, only sees half the letters. The letters in the frame may be made to spell a word, such as F R I E N D, so arranged that the letters F, I, and N are red, and R, E, and D green. If the patient, having had any ametropia corrected, sees all the letters and spells the word "friend," we know he has binocular vision; but if, *e.g.*, he only spells F I N, we know that he is using the eye with the red glass in front of it, and that the other eye is excluded from vision.

For binocular vision to exist in anisometropia the

difference in refraction between the two eyes—that is, the degree of anisometropia—must be small, although cases have been recorded where it has amounted to 6 D. Under these circumstances, although the magnitude and acuteness of the images in the two eyes are unequal, they overlap and help each other.

If each ciliary muscle could act independently, the anisometrope could very often correct each eye by a separate and independent accommodation in each eye; but it is generally believed that the same effort of accommodation is made on both sides, with the result that only one image is sharp. At the same time, it should be noted that when the anisometropia is of low degree, some patients may have the power of producing asymmetrical accommodation to a limited extent. If we place a convex glass of +.50 in front of one eye and a concave glass of −.50 in front of the other, and thus produce an anisometropia of 1 D, and attempt to read with the glasses, a very distinct feeling of strain is experienced, but whether this strain is brought about by actual asymmetrical accommodation or only by the attempt to produce it, it is difficult to say.

Treatment.—This varies considerably; we should expect that each eye should be fitted up with its correcting glass in all cases, but in practice we find this will not suit many patients; they have become so accustomed to the difference between the eyes that the removal of the difference not only confers no benefit, but proves irksome, and they may complain of dazzling, head-swimming, and headache.

No definite rule can be laid down; each case must be treated according to its individual requirements and according to the methods cited in the previous pages.

If the ametropia be of a low degree and binocular vision acute and easy at all distances, and if there be no asthenopia, glasses are not necessary.

When asthenopia does exist, place the proper correction in front of each eye and try the binocular effect; if this is borne by the patient, order these; if not, try various combinations. We find generally that in low degrees the patient prefers the same correction in both eyes, and that the correcting glass is weaker than that required by the most ametropic eye. For instance, suppose the right eye is emmetropic and the left hyperopic to the extent of 2 D, a plane glass in front of the right and + 2 in front of the left may not be accepted; the patient may prefer + 1 in front of both eyes, or + .5 in front of the right eye and + 1.5 in front of the left.

Full correction should be our aim, and we must get as near to it as we can, the patient's sensations being our guide. In the very young, these personal feelings may be ignored, and the full correction ordered for each eye, the glasses to be worn always.

It is a good plan, when ordering glasses for anisometropia, to deduct a little more for the cycloplegic from the most ametropic eye and a little less from the other. For instance, supposing under atropine a patient requires + 2 and + 5, reduce the difference in the final glasses by ordering + 1.5 and + 3.5.

2. The Eyes are used Alternately.—One eye may be emmetropic or slightly hyperopic, and is used for distance, and the other eye is myopic, and is used for near work.

Treatment.—If asthenopia be not present, the patient will not thank you to give him any glasses. Although he has lost binocular vision, he has gained other advantages; in some cases he can entirely dispense with muscular effort, his ciliary muscle and internal recti being rarely used.

When asthenopia exists we shall find, probably, that both eyes are ametropic, one more so than the other, and glasses are needed. The best plan is to give similar

glasses for both eyes. If both eyes are hyperopic, we give the glasses corresponding to the strongest hyperopic eye; this latter eye will then be used for distance and the other one for near work. If both eyes are myopic we give each the correcting glass of the weaker.

3. One Eye is Permanently excluded from Vision.—When the difference between the eyes is great, the most defective eye is little used, and tends to become amblyopic, if it be not so already. In such cases it is advisable to give a separate pair of glasses correcting this eye fully, and when the other eye is emmetropic to put a ground-glass on this side, and the patient should be made to practise with these glasses for a certain time every day. In very young patients it is best to exclude all vision with the good eye by means of a bandage. In "amblyopia exanopsia" occurring in patients with internal strabismus, this treatment patiently persevered in, has sometimes a most satisfactory result. I have seen the vision improved in many cases from $\frac{6}{60}$ to $\frac{6}{18}$ in six months. When the better eye is ametropic the correcting glass may be put in, and a clip worn over it while practising. The defective eye may never take its proper place in binocular vision, but in some cases it may become very useful, especially if any damage or disease should affect the good eye, and, moreover, the cosmetic result which sometimes occurs is considerable, for, if treated in time, the strabismus which so often appears in these cases may be prevented.

Bifocal Lenses.—When the eye is not looking through the centre of the lens a certain prismatic effect is produced, and the higher the lens the greater this will be. This will produce, for its correction, a certain amount of muscular strain, which will be all the more pronounced when it exists on one side only. To avoid this Mr. Dixey of New Bond Street has suggested a bifocal lens.

When, say, the right eye requires -2 and the left -6

for correction, the left lens should be reduced in size and the outside portion should be worked to the same curve as the right, as in Fig. 66. If the lenses are convex, the weaker glass should be thus reduced in size, and its margin made equal to the stronger.

Monocles.—When one eye only is used and that eye is ametropic, especially if this ametropia be myopia, a single eye-glass or monocle may be employed to correct vision. The glass should be set in a frame with a bracket, so that it is removed from contact with the skin and the lashes. If a cylinder be used the patient must be

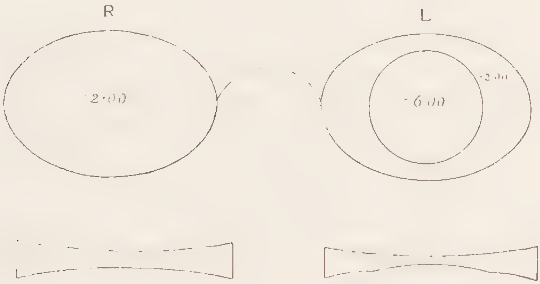


FIG. 66.

instructed to be careful always to place the glass in front of the eye in the proper manner, the hole in the frame for the cord serving as a guide.

When *presbyopia* is present with anisometropia, we might expect that in each eye the same addition would be made to the glass that we had already found was best tolerated for distant vision, but this is not so, and we have to make the same trials with the reading-glasses as we did for distant correction. For instance, one eye has a hyperopia of 2 and the other of 4, and the patient is 52: we should try + 4 and + 6 for reading, or if this be not comfortable + 4.5 and + 5.5, or + 5 in both eyes.

When one eye is permanently excluded, and the "good" eye is ametropic and presbyopic, **reversible spectacles** are useful, and do away with the necessity for two pairs of spectacles.

The distant correction is placed in one side, and the reading correction in the other. When the patient is walking, the distant correction is in front of the "good" eye and the reading glass in front of the useless eye, and when he wishes to read, he turns the spectacles upside down, and so brings the reading glass in front of the good eye, the bridge being made to fit the nose in either position.

To **recapitulate:**

No definite rule can be made for the correction of anisometropia.

The proper glasses can be found by trial only.

One patient may accept the full correction for each eye, while another prefers no glass at all. One patient takes the same correction in each eye, while another does better with a partial correction. Again, another class of patient accepts correction at times, as in reading, but not constantly. It may be generally stated that the older the patient, the more difficult is the case to treat satisfactorily, when the proper correction has never been worn.

Malingering.—A malingerer will sometimes pretend that one eye is blind, in order to escape war service, or to obtain damages after injury. Malingering is sometimes a symptom of hysteria. It may be detected by:

1. *The Prism Test.*—Both eyes being uncovered, a prism, base up or down, is placed before the "blind" eye. Diplopia is complained of if the eye is not blind, and the fraud is exposed.

2. *Snellen's Coloured Glasses* (see page 145).—This is a safer test. The malingerer may be aware, with the prism test, that the confession of diplopia exposes him; but he does not know that, with Snellen's test, he can read only half the letters with one eye. If he reads the whole word, he is detected.

CHAPTER XII.

APHAKIA.

PROPERLY speaking aphakia denotes an eye without a lens, the lens having been purposely removed by operation, or absorbed after needling, or accidentally lost through a perforating wound or ulcer, but we generally include under aphakia conditions in which the lens has been more or less completely dislocated (as in the old operation of "couching"), so that rays of light, passing into the eye, do not intercept any portion of it.

The absence of the lenticular images, found by holding a light near the eye (see page 29), and a tremulous iris are characteristic signs of this condition.

A strong convex glass has to be used to obtain distinct distant vision, unless high myopia be present. A convex glass of 12 D in the spectacle frame is about the equivalent of the lens in the eye, so that an emmetrope who becomes aphakic requires a +12 with which to see distant objects, and as all accommodation is lost we must add to this the equivalent of the accommodation effort for near vision; thus, to see at 33 cms. he requires $12+3=15$, and at 25 cm. $12+4=16$. After cataract extraction there is almost always a large amount of astigmatism "against the rule," and a cylinder of 1 to 2 D placed horizontally or nearly horizontally may improve vision considerably.* When a cylinder is required, the

* In some cases, for weeks after cataract extraction the astigmatism is very high, and gradually diminishes. It is not wise to order cataract glasses until about three months after the operation.

ideal method is to divide the sphere equally on both surfaces, and to add the cylinder to one surface (see Toric Lenses, page 11).

If the patient were myopic originally, a weaker convex glass is required, and if he had a myopia of 12 D he ought to require no glass at all for distant vision (see Treatment of High Myopia by removing the Lens, page 107); on the other hand, hyperopic patients require a stronger glass, sometimes 15 or 16 D for distant vision.

If the correction be not satisfactory, an examination of the patient in the dark room with focal illumination and a strong lens will probably reveal an opaque capsule, which will require needling before any good result is obtained with glasses.

CHAPTER XIII.

MUSCULAR ASTHENOPIA.

We have seen (page 42) that in ideal binocular vision the visual axes are parallel when the eyes are at rest, E R (Fig. 67, A), and that when the eyes accommodate for a point P, both eyes converge to that point; that in normal vision, if we destroy the possibility of fusion, that convergence lags behind accommodation,

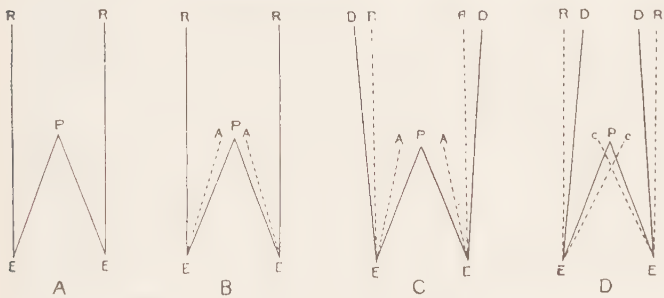


Fig. 67.

and instead of converging for P, the visual axes are in the direction E A (Fig. 67, B), the difference between A and P being the "fusion supplement." We have also seen that if the position of rest is one of divergence (Fig. 67, C), A is further removed from P, and the "fusion supplement" is larger. Now, this position of divergence at rest is caused by "muscular in-

sufficiency," in this case of the internal recti muscles. This means that the internal recti are insufficient to produce parallelism without active muscular contraction which the demand for binocular vision necessitates during all the waking hours; hence the muscles are never at rest, and when the necessity for convergence arises, the interni start with a deficit of power. The constant using up of part of the convergence power fatigues the internal recti muscles, and the positive part of the amplitude of convergence will be found very much diminished. Landolt says: "In all cases where the positive convergence does not reach 9 metre-angles, asthenopic troubles may become developed when the eyes are used for near vision. This is, of course, the more apt to happen, the more the maximum of this function falls below the given measure."

The amplitude of convergence may be quite up to the average, but if the positive part of it is too small, this indicates the presence of insufficiency of the internal recti and the liability to asthenopia. Take a patient who has 3 m.a. of latent divergence, and whose convergence near point is 14 cms.: we have

$$\begin{aligned} ca &= 7 - (-3) \\ &= 7 + 3 \\ &= 10 \text{ m.a.} \end{aligned}$$

10 m.a. of amplitude of convergence would be quite sufficient if it were all positive, but only 7 are positive, and only from $\frac{1}{3}$ to $\frac{1}{4}$ of this power should be used for any length of time, which means that only about 2 m.a. should be used, which would be useless for near work. Remove the insufficiency—that is, remove his latent divergence—and he will not only have 10 m.a. of positive convergence power, but even more, for the constant fatigue of the internal recti, produced by the work of overcoming the latent divergence, will be removed.

The term "insufficiency" has been used in such vague ways that it is most important to define accurately what we mean by it. There are two kinds of "insufficiency":

1. Due to *relative* weakness of a muscle (**Peripheral Motor Asthenopia**).

Insufficiency of a muscle due to *relative* weakness means that "a particular muscle is *relatively* weaker than its opponent, so that in 'static' and 'dynamic' vision extra impulses have to pass to that muscle in order to produce perfect fusion." An insufficient muscle is not necessarily weak. It is insufficient because its opponent through spasm or preponderance (*uebergewicht*, as Graefe calls it) is "*too sufficient*"; hence in the case of insufficiency of the interni, although the muscles may be insufficient for convergence, they may be perfectly able to take their part in the associated movements of the eyes to either side.

2. Due to *absolute* weakness of a muscle, either of local or central origin (**Central Motor Asthenopia**).

Insufficiency, especially in reference to convergence (commonly called convergence insufficiency) may mean inability of the muscle to act normally irrespective of its opponent.

The patient appears to have no power to supply a "fusion supplement."

Insufficiency may be present in any of the muscles; if the visual axes at rest are convergent, the external recti muscles are insufficient to produce parallelism (Fig. 67, D). In this case binocular distant vision, which should be perfect rest to the eyes, necessitates the constant contraction of the external recti, and they are liable to become fatigued and to cause eyestrain. During convergence, also, we may find latent convergence, the eyes converging to a point nearer than P (Fig. 67, D), and the necessity for fusion demands contraction of the

external recti to overcome this over-action of the interni: hence fatigue. And so with the other muscles: if one muscle by spasm or preponderance over its opponent prevents the eyes from assuming the normal position when at rest, there is liability to fatigue and asthenopia; whether it manifests itself or not (there are a large number of cases of insufficiency which never produce any symptoms) depends entirely on the amount of insufficiency and the nervous condition of the individual.

When we consider that on the *relative* strength of the muscles of the eyeball depends the position of the eye, and that the smallest amount of preponderating strength or the slightest amount of weakness of one muscle will cause a displacement or a tendency to displacement (*i.e.*, a latent deviation) of the eyes, we can only wonder that the condition of parallelism of the visual axes in distant vision is so constantly found. The secret is, that the desire for binocular vision, obtained by the fusion of the two images, acts as an unconscious stimulus to the weaker muscle, and masks the relative weakness. If binocular vision be impossible through the sight of one eye being very much inferior, then the stimulus is absent, and the eyes assume a divergent or convergent position of rest, which becomes manifest, and is then a squint. We must be careful not to use the term "insufficiency" in connection with squint; it is quite unnecessary, and causes a great deal of confusion to apply the term to, for instance, an atrophied internal rectus in an old divergent strabismus. An insufficiency, if unrelieved, may pass into a squint, just as congestion may pass into inflammation, but they are two distinct things.

In estimating insufficiency of a muscle we must beware of attaching too much importance to *one* examination; a muscle may be insufficient at one time and not at another.

The following terms, suggested by Stevens of New

York, are now in common use, in designating the different forms of insufficiency (see Plate, page 42).

Orthophoria = visual axes parallel, and lying in the same horizontal plane.

Heterophoria = visual axes not parallel or not in the same horizontal plane; divided into:

1. Exophoria. The eyes tend to turn out: insufficiency of the interni.

2. Esophoria. The eyes tend to turn in: insufficiency of externi.

3. Hyperphoria. One eye tends to be on a higher level than the other, due to insufficiency of the superior or inferior rectus.

4. Insufficiency of the oblique muscles—

(*a*) Hyperesophoria, a tendency up and in.
(*b*) Hyperexophoria, a tendency up and out.

1. **Exophoria** (*Insufficiency of the Internal Recti—Convergence Strain*).—"**Convergence Insufficiency**" is a latent external squint, overcome for the time by the strong desire for single vision.

Strain of the internal recti is essentially dependent upon binocular vision, and persons who have not the advantage of binocular vision, by a compensation of nature cannot suffer from this trouble.

Tests for Insufficiency of the Interni.—We have seen that the Maddox test is the best and simplest. If we find latent divergence for distance, or latent divergence of more than a metre angle at $\frac{1}{4}$ metre, or both, we can positively assert that the interni are insufficient, and we can confirm this by ascertaining the amplitude of convergence, the ordinary working distance of the patient, and the reserve power of convergence.

Except in neurasthenic insufficiency, the estimation of the adducting power of the interni by prisms is not of

much use. We may get an adducting power of 30° or 40°, and yet if the externi are "preponderating" we shall have insufficiency present.

2. **Esophoria** (*Insufficiency of the External Recti*).—When latent convergence is demonstrated for distance, we say that we have "insufficiency" of the external recti—that is, in the position of rest the externi are relatively weak. If there be no manifest convergence, the visual axes assume a parallel condition; but to maintain this, active contraction of the external recti must take place always, when distant vision is used, in order to prevent diplopia. Latent convergence is very common, but, in the majority of cases, gives rise to no symptoms. The explanation is, that the latent deviation is slight, and in our civilized state active use of the eyes is mostly associated with a necessary convergent condition. When the latent convergence is excessive we may get symptoms of muscular asthenopia.

Test for Insufficiency of the Externi.—When the Maddox test reveals latent convergence for distance or for $\frac{1}{4}$ metre, it is present.

The abducting power of normal externi is equal to a prism of 7° or 8°.

Insufficiency of the externi is generally associated with hyperopia.

3. **Hyperphoria** (*Insufficiency of the Superior or Inferior Rectus*).—To judge from the writings of American ophthalmologists, this is very much more common in America than it is here.

I have proved hyperphoria of a very small amount to be present in many cases that exhibited no symptoms of asthenopia.

4. **Insufficiency of the Oblique Muscles.**—This is the result of the superior oblique of either eye being too strong for its inferior, or *vice versâ*. The parallelism of the vertical meridians of the corneæ is maintained by the

equilibrium of these muscles; hence, when one muscle is weaker, excessive work must be put upon it in order to preserve the parallelism, and a train of nervous symptoms are thus brought on, for which at present there seems no hope of cure.

The presence of all these insufficiencies is revealed by the Maddox glass rod test.

Causes of Muscular Asthenopia.—Heterophoria, the result of muscular insufficiency, in most cases lies at the root of the causes of muscular asthenopia (which, however, is much less common than ciliary asthenopia).

Table of Causes.

In Emmetropia, due to:
1. Abuse in the healthy (excessive or prolonged convergence).
2. Nervo-muscular debility—
   (*a*) Neurasthenia.
   (*b*) General debility.
3. Congenital defect.

In Ametropia, in:
1. Hyperopia (high).
2. Myopia.
3. Astigmatism.
4. Anisometropia.

Muscular Asthenopia in Emmetropia.

In the Healthy.—As ciliary strain generally accompanies convergent strain, it is difficult to distinguish sometimes between the two forms. Ciliary strain is more common than the latter, as we should expect, for the internal recti can stand more strain without showing fatigue than the delicate ciliary muscles. In practice patients suffering from this form of muscular asthenopia, are mostly jewellers and engravers who do not use a "watchmaker's glass" and sit at very fine work for many hours a day.

Neurasthenic Muscular Asthenopia.—This is the central

motor asthenopia of Landolt. Neurasthenics exhibit inability to maintain prolonged convergence, through the increased tendency to fatigue of the internal recti, which share in the loss of nerve power of the rest of the system. The total amplitude of convergence is often very small.

Neuropathic Muscular Asthenopia occurs in those recovering from severe illness or accident, or in those suffering from anæmia, or any other debilitating constitutional disease.

Congenital Defect.—The externus may be inserted too far forward or the internus too far back, or *vice versâ*.

Treatment.—The treatment of those whose sight is normal, and whose muscular asthenopia is due only to fatigue, consists simply in directing them to put their work further back.

We may give these patients weak convex glasses with the object of making larger images and enabling the work to be put further from the eyes, but they must be made to distinctly understand this, as otherwise they will be tempted to approach their work nearer to the eyes, which, of course, will not remove, but will aggravate the strain.

Orthoptic training, or gymnastic exercises, devised by Dr. Dyer in connection with the ciliary muscles, can be, with very great benefit, extended to the extrinsic muscles. For strengthening the internal recti we employ properly regulated convergence for a short time at different periods of the day, the time to be gradually increased as the muscles increase in strength, measured, of course, by the tests previously cited. For strengthening the external recti we must employ prisms with their base in. The best plan is to provide the patient with a square prism, say 2°, and tell him to practise fusion several times a day, and when this is accomplished with ease we can gradually increase the strength of the prism until the "insufficiency" disappears.

When the muscular asthenopia is the result of defective or enfeebled muscles, we must first of all improve the general health by enjoining out-door exercise and attention to the bowels, and by the administration of tonics, and then, remembering that absolute rest will only tend to increase the weakness, we must commence regular exercise of convergence (if we are dealing with "convergence insufficiency") for short periods, gradually increased, and forbid the patient to use the eyes for near work except at these times. To carry out this treatment in young subjects the use of a cycloplegic is most helpful. Forced or prolonged efforts of convergence would only help to increase the fatigue of the internal recti, and therefore we must commence with very short efforts, and increase those efforts very slowly.

Doyne's stereoscope is very useful for the orthoptic training of the eyes.

As a last resource weak prisms, with their base in, may be ordered for convergence insufficiency; with their help the convergence effort is diminished, but all hope of the muscles regaining their normal condition must be abandoned, unless the prisms are only used temporarily while the general condition is being improved. Prisms employed in this way never *cure* "insufficiency," they only *relieve* it.

Muscular Asthenopia in Ametropia.

1. *Hyperopia.*—(*a*) Insufficiency of the internal recti, generally the result of fatigue from excessive convergence, occurs (i.) in young hyperopes suffering from spasm of the ciliary muscle, who are thus made artificially myopic. The eyes are focussed for very near work, and consequently undue convergence has to be exercised in order to see binocularly. (ii.) In high hyperopia; to supply the deficiency of distinctness, the patient approaches his work very near his eyes in order to get larger retinal

images. Here again the patient strains his convergence.

(*b*) Insufficiency of the external recti. We have seen that in hyperopia accommodation is required in excess of convergence, and unless the two can be dissociated the hyperope must converge to a nearer point than is necessary. This over-contraction of the interni causes latent convergence for distance and also for the near point (Fig 67, D); the external recti become insufficient, and extra impulses must pass down to these muscles in order to obtain fusion vision. This may lead to fatigue and asthenopia, which, however, soon disappear, owing to the development of a convergent squint and loss of binocular vision (see page 85) ; for this reason asthenopia, as a result of insufficiency of the externi in hyperopia, is not at all common.

Treatment.—*Convergence Insufficiency.*—The regular instillation of atropine and proper correction of the error of refraction, with special injunction to cease for some time from all close work, will remove the strain. The high hyperope will find that suitable glasses will enable him to put back his work considerably, and thus remove the strain on his convergence.

Insufficiency of the Externi.—By putting the hyperope into glasses we re-establish the harmony between convergence and accommodation, remove the spasm of the internal recti, and consequently also the insufficiency of the externi, restoring the balance of all the muscles. One of the pleasantest things to do in ophthalmic work is to cure a squint, or a tendency to squint, by simply giving the patient glasses. If parents would only realize that, in a large number of cases, this can be done by bringing the child early enough—*i.e.*, before the latent squint has become manifest, or possibly during the early period of the manifest squint—there would be fewer squints.

2. *Myopia.*—Convergence insufficiency is so associated with myopia that the subject has been fully dealt with under Myopia (page 93).

3. *Astigmatism.*—Muscular asthenopia in astigmatism is generally due to convergence insufficiency, and is associated with myopic astigmatism.

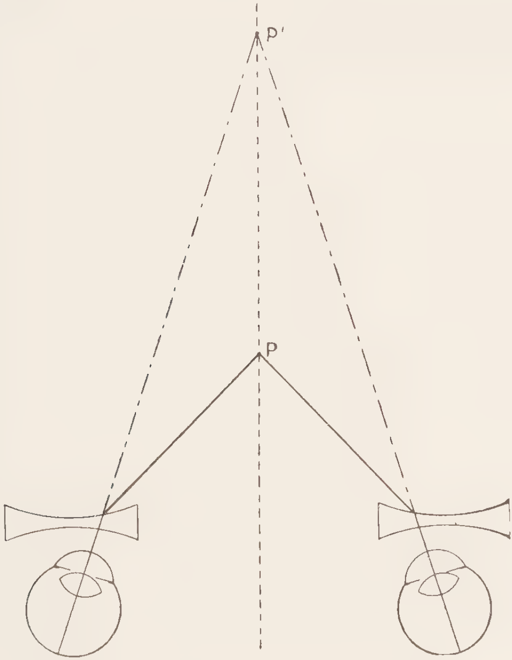


FIG. 68.

By partially closing his eyes the sufferer from compound myopic astigmatism cuts off his vertical rays, and thus clears his images and makes himself a simple myope, and the greater the degree of his horizontal myopia the nearer will be his far point, and the greater the conver-

gence strain. Hence in astigmatism "contrary to the rule," when the horizontal myopia is higher, the liability to asthenopia is greater still.

Although convergence insufficiency is the commonest, any of the forms of insufficiency may be associated with astigmatism.

4. *Anisometropia.*—Muscular asthenopia can only occur in the first variety of this defect—viz., when binocular vision exists.

Treatment by Prisms or Decentring. — When we cannot hope to restore the muscles of the eye to a practically normal condition, we may aid them and remove the asthenopia by giving prisms, or, if glasses are worn, by combining with them prisms, or by decentring the glasses.

If the internal recti are insufficient, the prism should be placed base inwards, or if decentring is preferred concave glasses should be decentred outwards (Fig. 68) and convex glasses decentred inwards, in both of which cases the part of the lens the patient looks through will be converted into a prism with its base inwards.

If the external recti are insufficient, the prism should be placed base outwards, concaves decentred inwards, and convexes, outwards (Fig. 69). In both Figs. 68 and 69, P is the object looked at, and the decentring of the lenses displaces the apparent position of P to P′. It the superior or inferior rectus is insufficient, the prism should be placed base up or down, according to the effect required.

Method of Finding the Amount of Decentring necessary to Produce the Effect of a given Prism in a given Lens (Ward Holden).—Take 8.7 mm. as the distance a lens of 1 D must be moved, to produce the effect of a prism 1°, as the unit, multiply 8.7 mm. by the number of the prism whose effect is required, and divide the product by the number of the lens in dioptres. Thus the effect of a

prism 3° in a lens 7 D is obtained by decentring that lens to the extent of $\frac{8.7 \times 3}{7}$ mm. = 3.7 mm.

The use of prisms is limited to about 4° in front of each eye, as any stronger prism than this would make the glasses too heavy.

Treatment by Tenotomy.—There is no doubt that in certain picked cases great benefit results from tenotomy.

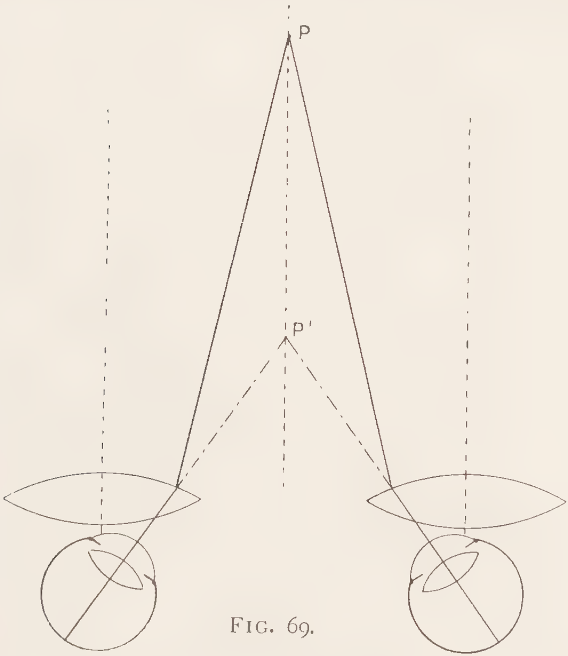


FIG. 69.

Such cases are examples of "peripheral motor asthenopia," as Landolt calls them; but in neurasthenics and in those suffering from high myopia, when the convergence insufficiency is due to a very small amplitude of convergence no good results follow operations, as in the case illustrated by Fig. 70 *c*.

As a general rule, tenotomy for asthenopia is unnecessary, as correction of the refraction error, constitutional treatment, and orthoptic training, will effect a cure. But when the range of convergence is large, but too much of it is on the negative side, tenotomy of one or both externi, or advancement of one or both interni, cures the asthenopia, because it removes the negative convergence power to the positive side (see page 154). For instance, Landolt gives an example of a case (Fig. 70, *a*) where before the

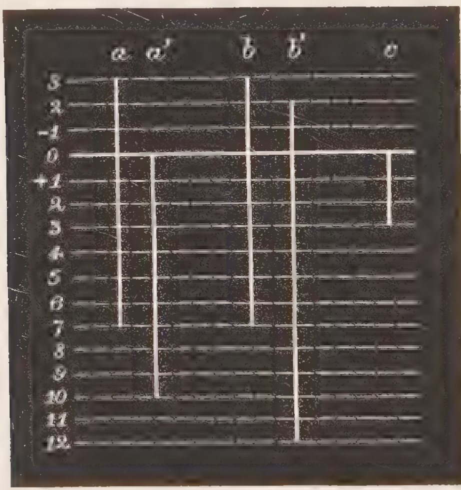


FIG. 70.

operation there was 3 m.a. of divergence, and the convergence near point was 14 cms. off, with asthenopia. In this case ca $= \frac{100}{14} - (-3) = \frac{100}{14} + 3 = 10$ m.a., but only 7 of these 10 metre angles of convergence power were available; tenotomy of the external rectus removed the divergence, the whole of the 10 m.a. became available, and the asthenopia disappeared (Fig. 70, *a'*).

Fig. 70, *b*, illustrates another case which was cured by

tenotomy; here the result was not so perfect as in the first case, Fig. 70, *a*.

Recapitulation.—Muscular asthenopia is generally to be traced to some error of refraction which necessitates too close approximation of the eyes to the work, or in those who are normal sighted to too prolonged application to near work; hence it is in a large number of cases due to strain on the convergence muscles of the eye—*i.e.*, the internal recti. Equilibrium of all the ocular muscles, producing complete parallelism of the visual axes, is rare, but the amount of deviation in the majority of cases is so slight that it produces no symptoms, and can be ignored.

Muscular asthenopia occurs in two forms: one, "peripheral motor asthenopia," in which the balance of the ocular muscles is destroyed by the preponderance of one or more muscles, causing so-called "insufficiency" of the opponents, which muscles need not be abnormally weak; the other, "central motor asthenopia," due to actual weakness of the muscles, which are insufficient. Insufficiency of the externi is generally associated with hyperopia, that of the interni, with myopia.

The treatment consists essentially in removing the necessity for too great convergence. The correction of any error of refraction is of first importance. If this fails to remove the strain, orthoptic training of the insufficient muscle should be tried, with constitutional treatment. Tenotomy of the preponderating muscle is justifiable only when other means have failed, and then only in peripheral motor asthenopia, when the amplitude of convergence is not much diminished.

Correcting prisms can relieve or remove the symptoms only while they are in use, and for this reason should be employed only as a last resource. Decentring of the glasses may take the place of prisms.

CHAPTER XIV.

STRABISMUS.

Squint.—A heterophoria, or latent squint, may at any time become heterotropia, or manifest squint, if the necessary muscular effort to preserve parallelism cannot be made or maintained. Thus, insufficiency of the internal recti in myopia, produced by excessive convergence, may become temporarily or permanently a divergent squint, and we have already seen how a convergent squint develops when the patient cannot use his accommodation in excess of his convergence in Hyperopia (p. 85).

Varieties of Squint.—(1) *Concomitant*, in which the squinting eye moves with its fellow, and always deviates to the same degree from the correct position.

(2) *Paralytic*, when the movement of the squinting eye is restricted by paralysis of the muscle.

We shall deal, in these pages, only with the first variety.

Forms of Concomitant Squint. — 1. *Convergent* — Internal squint (esotropia).

If the squinting eye is not amblyopic there is homonymous diplopia. In Fig. 71, R, the right eye, is fixing the object O, but L, the left eye, which is squinting in, receives the image of O at M′, which is on the nasal side of the macula M; hence the left eye projects O to the left or *same* side.

2. *Divergent* strabismus—External squint (exotropia).

If the squinting eye is not amblyopic there is heteronymous or crossed diplopia. In Fig. 72, R, the right eye, is fixing the object O, but L, the left eye, is squinting out, and receives the image of O at M′, which is on the tem-

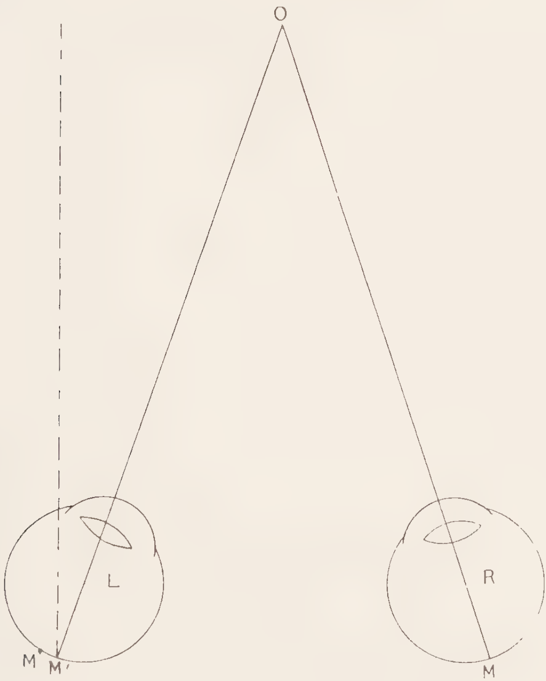


FIG. 71.—HOMONYMOUS DIPLOPIA.

poral side of the macula M; hence L projects O to the right or *opposite* side.

3. *Vertical* strabismus (hypertropia), in which the visual axis of one eye is deviated upwards.

These three different forms of concomitant squint may be:

1. *Constant*, in which one eye is always the squinting eye. This condition is also called *monolateral*.

2. *Alternating*, in which either eye can fix, the fellow squinting; in these cases the vision of both eyes is generally equally good. Squints may also be *periodic* or *intermittent*. When the squint is developing—that is, at

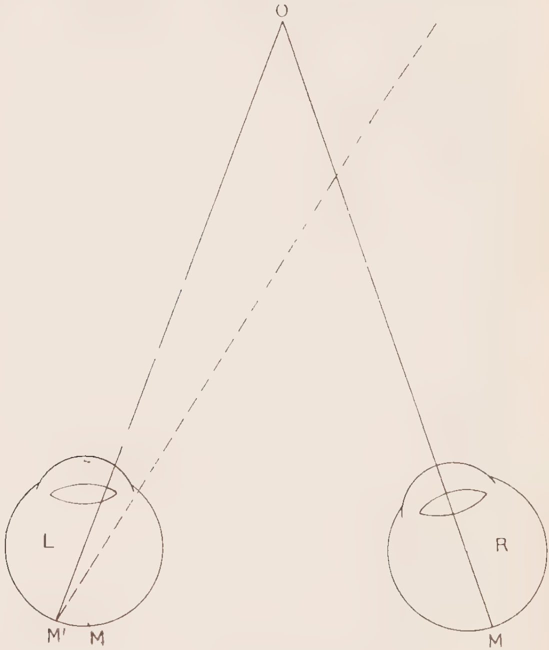


FIG. 72.—HETERONYMOUS DIPLOPIA.

the time that the heterophoria is passing into a heterotropia—the latter may be manifested only after fatigue or when certain constitutional conditions are present.

Angle Alpha and Angle Gamma.—We must be careful to distinguish between a real squint and an apparent squint. We may have in hyperopia an apparent divergent squint,

and in myopia an apparent convergent squint, due to the visual and optic axes not coinciding.

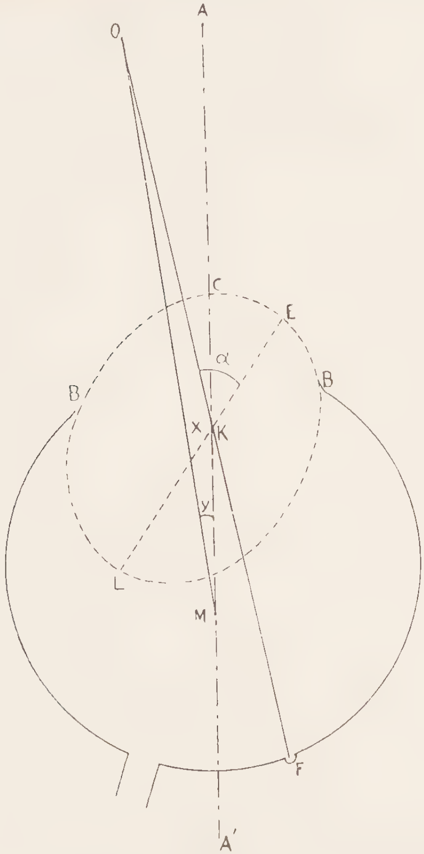


FIG. 73.—A SCHEMATIC FIGURE TO SHOW ANGLES α AND γ. (AFTER LANDOLT.)

A A′ Optic axis; K, Nodal point; M, Centre of rotation; C, Centre of cornea; B B, Base of cornea; E L, Major axis of the corneal ellipse; F, Fovea centralis; O, Point of fixation; K O, Line of vision; M O, Line of fixation; O X E, Angle α; O M A, Angle γ.

When the optic axis passes through the fovea it coincides with the line of vision or line of sight, and also with the line of fixation; but the exception to this is the rule, and an angle is formed by the line of fixation M O with the axis A A′. This angle is called the angle gamma, "γ" (O M A, Fig. 73), and it is *positive*, as in Fig. 73, when the fovea is on the outer side of the optic axis. The angle γ is generally positive in emmetropia and hyperopia, and in some cases

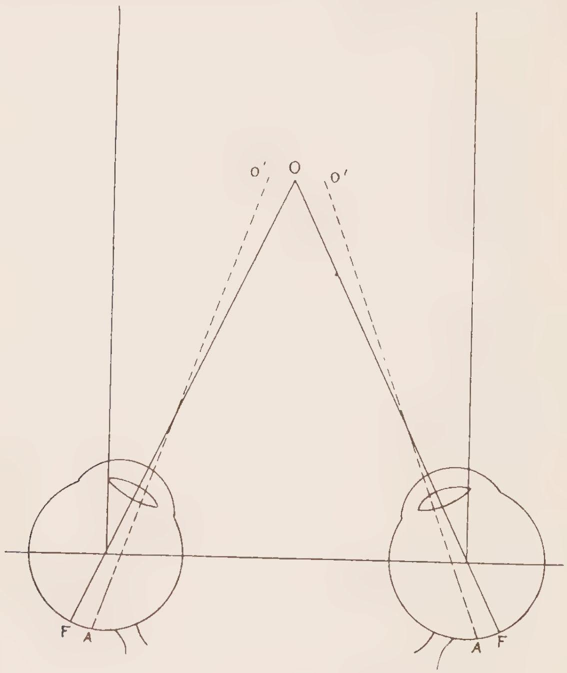


FIG. 74.

of hyperopia the angle is so great (amounting even to 10°) that it gives the eyes an appearance of divergence (see Fig. 74)—an apparent divergent squint; the eyes, although looking at and fixing the point O, appear divergent in the direction A O′.

The angle gamma is *negative* when the fovea (F, Fig. 75) is on the inner side of the optic axis—that is, between the optic axis and the optic nerve. In some cases of myopia this is so marked as

to give the eyes the appearance of convergence (see Fig. 75)—an *apparent convergent squint*.

The angle O K A (Fig. 73), made by the *line of vision* and the optic axis, may be considered identical with the angle γ (O M A). The angle alpha (O X E, Fig. 73) is the angle formed by the major axis of the

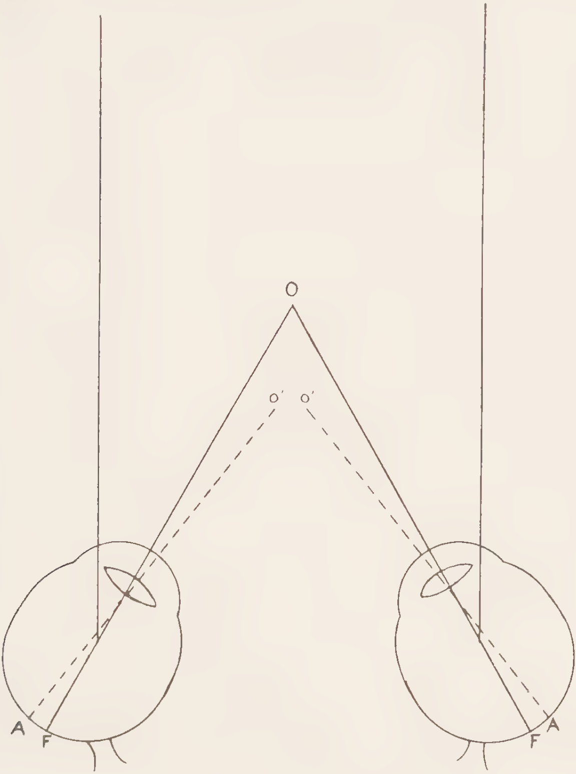


FIG. 75.

corneal ellipse (the cornea resembling in its central area an ellipsoid of revolution) with the line of vision. It is spoken of as positive when, as in Fig. 73, the anterior portion of the corneal axis is situated on the outer side of the line of vision, and negative when it is on the inner side.

The Causes of Concomitant Squint.—Any cause which disturbs the muscular equilibrium may be the starting-point of a squint, so that any of the causes of heterophoria (see page 159) may be the factors in the causation of a squint, but the chief are:

1. *Ametropia.*—We have already seen how in hyperopia (p. 85), when the patient has to use his accommodation in excess of his convergence, a convergent squint is developed if he can dissociate the two; he has to choose between indistinct binocular vision and clear monocular vision with squint, and he chooses the latter.

Again, in myopia he has to use his convergence in excess of his accommodation, "insufficiency" of the interni develops, and in time an external squint is manifest.

2. *Anatomical Peculiarities.*—A broad face with a large interpupillary distance means the necessity for greater convergence; a narrow orbit with a long myopic eye prevents freedom of movement of the eye, and consequently causes greater strain and the necessity for greater muscular effort in convergence. The external rectus may be inserted into the eye too far forward, or the internal rectus too far back, or *vice versâ.*

Any of these conditions, especially if associated with ametropia, may be strong factors in the causation of a squint.

3. *Amblyopia.*—Any cause which reduces the visual acuity of one eye tends to develop a squint, especially if a heterophoria or latent disturbance of equilibrium pre-exist. Among the commonest causes may be mentioned corneal opacities, cataract, and intraocular diseases. Thus, a patient with heterophoria has an attack of keratitis in one eye, corneal opacities result which lower the visual acuity of this eye, and a manifest squint develops.

The amblyopia may be congenital.

Note.—This amblyopia, which causes or helps to cause

a squint, must not be confused with the amblyopia which is the *result* of the squint, and which develops through the non-use of the eye. When a squint develops, diplopia must occur at first, and to get rid of this diplopia the brain refuses to recognise the image from the squinting eye; this form is called *Amblyopia Exanopsia.*

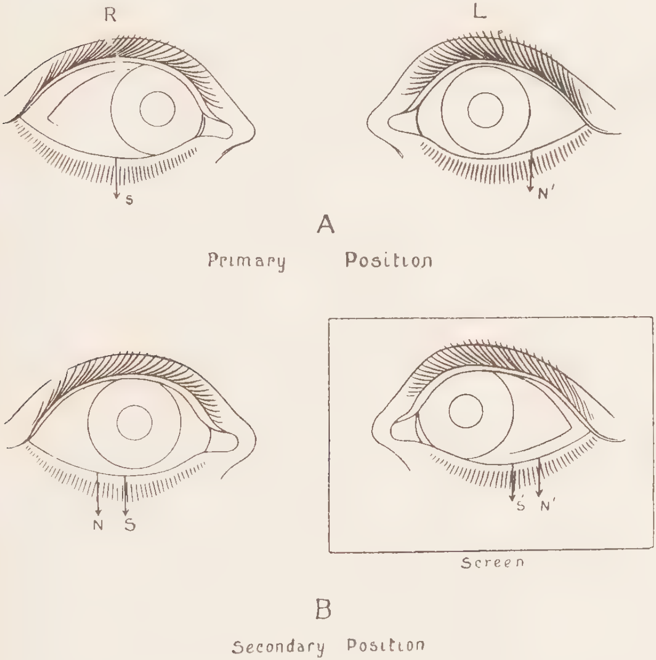


FIG. 76.

To sum up, then, squint is the result of two chief factors:

1. Diminished visual acuity of one eye, generally due to errors of refraction, opacities of the media, or intra-ocular disease, and

2. Pre-existing heteropheria.

The Diagnosis and Measurement of Concomitant Squint.—Let us proceed to measure a convergent squint.

Make the patient fix an object, say, a couple of metres from the eyes, taking care to place the object midway between the two eyes. Let us suppose that the left eye fixes the object and the right eye squints in: we note the external margin of the cornea of both eyes by making a small ink spot on the lower lid; let S be this mark on the right eye (Fig. 76) and N′ on the left. We now cover the left eye with a screen, and tell our patient to fix the object again; this he does with the right eye, and we notice a marked excursion of this eye; we now note the position of the external margin of the cornea N. The distance N S is the **primary deviation.**

When the left eye is covered and the patient is fixing with the right eye, if we look behind the screen we notice that the left eye makes a distinct incursion, and if we mark on the lid the two positions of this eye we get the distance S′ N′ as representing the **secondary deviation**, which is equal to the primary deviation. This enables us to diagnose very easily between a concomitant and a paralytic squint, for in the latter the secondary deviation is always very much greater than the primary. We measure a divergent squint in the same manner.

When the squinting eye is blind, we must use a strabismometer (Fig. 77), and read off on the scale the amount of the squint in millimetres.

A much more reliable method is to measure the amount of squint by the perimeter (Fig. 78). Placing our patient so that the squinting eye is opposite the fixation point F, and with both eyes uncovered, we direct him to look at a distant point D, the squinting eye and F and D being all in one line. We now hold a small candle or match at the fixation point F, and gradually move it along the arc, looking directly behind the candle

for its image reflected on the cornea of the squinting eye; when the image is in the centre of the pupil we read off the position of the candle on the arc, and the degree mark represents the angle of the strabismus.

Treatment.—(1) *Convergent Strabismus.*—Almost 80 per cent. of patients suffering from convergent strabismus are hyperopes, and the defect is manifested very early in life—in fact, when the child begins to use his eyes for near vision, looking at picture books, etc.; the

FIG. 77.

majority of such patients develop a squint about the age of three.

The squint as a rule develops slowly, and the parents are not the first to notice it. They generally assign as the cause, an illness such as measles, or the imitation of a squinting companion.

The first thing to do is to put the eyes under atropine for some weeks, and except in bad cases the squint entirely disappears when the eyes are fully under a cycloplegic. The refraction is then taken by retinoscopy, and the full correction less 1 D is ordered in large oval or

circular spectacles to be worn always. With an intelligent quiet child spectacles may be ordered at three

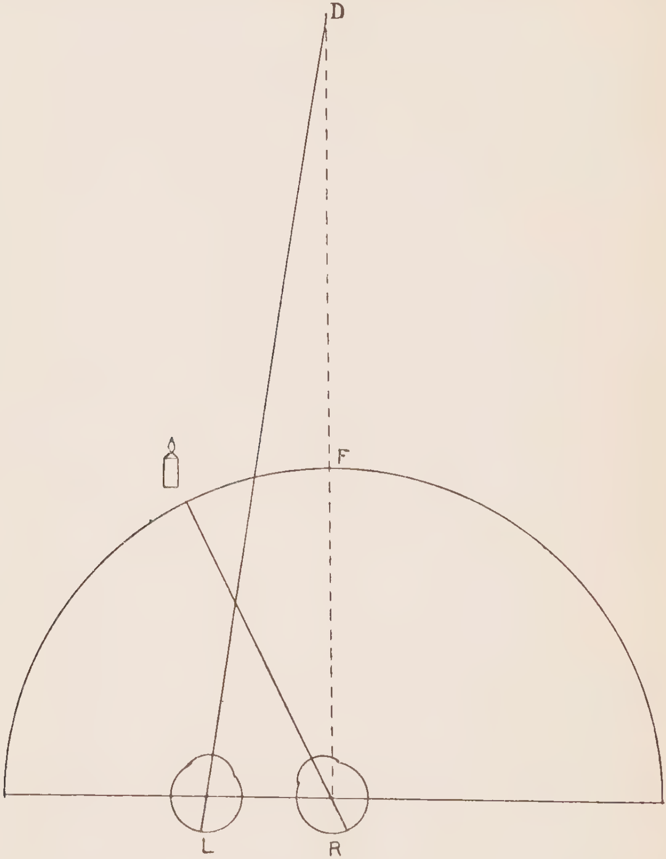


FIG. 78.

years of age, with instructions, of course, for their removal when the child is romping.

The atropine should be continued for some weeks

after the glasses are ordered, and be very gradually stopped. If the child is too young for glasses, the eyes should be kept mildly under atropine, say once a day for a month, and then, stopping for a fortnight, the atropine should be used again for a month, and so on.

The object of this is to prevent the squint becoming "fixed," which occurs through the internal rectus becoming shorter and stronger than its opponent.

If the atropine removes the squint, as a rule the glasses will also do so.

Be careful to insist upon the *constant* use of the glasses, and inform the parents that this treatment will probably have to be persevered in for years.

Every year the child should be put under atropine, and the eyes again refracted, as the tendency is for the eyes to become more normal and consequently less hyperopic. If the atropine, and afterwards the glasses, do not remove the squint, the treatment should be persevered in for six months or a year, and then the question of operative interference will have to be considered.

When there is any improvement with atropine or glasses, and when the squinting eye is not becoming more amblyopic (if it were not so originally), postpone operating, if possible, till the child is nine or ten years old; but when the squint is very bad, and glasses are of no use, operate by dividing the internal rectus, or by advancing the external rectus, or both.

As the squinting eye is generally amblyopic, the child should be made to practise it, by placing an opaque clip on the glass of the good eye, or, what is better still, especially with the very young, by bandaging up the good eye, and forcing the bad eye to read for a short time every day. In many cases this treatment results in great improvement of vision (see page 148).

The treatment by atropine and glasses, which is so efficacious in the young, is naturally much less so in older

patients who have had the squint for some years. The internal rectus has become permanently shortened, and the squinting eye is almost blind; but the spectacle treatment should be given a fair trial.

NOTE.—Never divide *both* internal recti. If the division of that of the squinting eye is not sufficient, then the external rectus must be advanced; division of both internal recti generally leads to divergent strabismus later.

Worth maintains that the one essential cause of convergent squint is a defective development of the fusion faculty. He considers the orthoptic training the most important part of the treatment, and insists that the training cannot be begun too early. He has devised an instrument called the amblyoscope, which is on the principle of the stereoscope; each eye looks through a separate tube, and a different part of the whole picture is placed before each tube, and so arranged that when both eyes are being used these two portions are fused into one picture. These tubes are not fixed together, but can be separated to any angle, and thus adjusted to the particular squint (see *Trans. Oph. Soc.*, vol. xxi., p. 245).

(2) *Divergent Strabismus.*—This condition is rarely seen in young children, and mostly develops at puberty or later —in fact, when myopia is progressing. By stopping undue convergence, and so helping to restore the fatigued internal recti, we may cure slight cases at the onset by putting the patient into glasses; but it is very uncertain, and in the majority of cases when once the "insufficiency" has passed into a squint, nothing short of operating is any good. This consists in mild cases in dividing the external rectus, and when this is not sufficient, in advancing the internal rectus. Training the eye, and so trying to reduce the amblyopia, should also be resorted to. When the squint is not very marked give the glasses and the orthoptic training a fair trial of, say, six months, before resorting to operation.

CHAPTER XV.

RETINAL ASTHENOPIA.

BESIDES accommodative and muscular asthenopia, which have already been discussed, there is a third form of eyestrain, known as retinal asthenopia. Under normal conditions the retina becomes exhausted when exposed to light, and the negative after-image is an example of this normal exhaustion.

Retinal asthenopia is an exaggeration of this, and implies an abnormally rapid exhaustion and fatigue of the nerve elements. It may appear in persons otherwise perfectly healthy, but is more commonly associated with nervous debility.

Causes.—1. *Over-use of the eyes.*

2. *Admission of too much light* into the eyes, due to—

(*a*) Glare of the sun.
(*b*) Glare of snow (snow-blindness).
(*c*) Glare of electric light.
(*d*) Lightning.
(*e*) Mydriasis, or any cause, such as cataract extraction with iridectomy, that causes an abnormally enlarged pupil. (Erythropsia or "red-vision" is sometimes a prominent symptom in these cases.)

3. *Neurasthenia* and exhaustion from disease.

4. *Reflex*, occurring chiefly in women, and then mostly due to some uterine or ovarian disturbance.

Symptoms.—These may be very slight, and consist of moderate photophobia and discomfort when in a bright light. On the other hand, the photophobia may be intense, associated with pain in and around the eyes, intense headache, lachrymation, and conjunctivitis. Concentric contraction of the visual field is a very characteristic symptom of this disease in neurasthenics.

As a rule, there is no visible ophthalmoscopic change, and the acuteness of vision is normal. However, many cases have been

recorded where distinct changes were visible; the vessels engorged, and the disc hyperæmic. In "sun-blindness," choroiditis and retino-choroiditis are not at all uncommon.

Night-blindness.—All healthy persons on first entering a dark room experience an inability to see, the extent of which varies with the intensity of the light they leave and the darkness of the room; in a short time physiological adaptation takes place, and objects become more and more discernible—they were temporarily "night-blind." This condition, exaggerated, occurs as a symptom of retinal exhaustion due to prolonged exposure to a great glare, such as is produced by the sun shining on a large expanse of snow, chalk, sea or sand, and is specially liable to attack those who are exhausted by fatigue, or by disease such as scurvy. This "idiopathic night-blindness" is unaccompanied by any retinal change, and is thus distinguished from the pathological variety; it manifests itself by a great diminution in the visual acuity, amounting often to blindness, when the light, from any cause, is reduced.

Treatment.—The treatment is simple and the cure generally complete. In cases where night-blindness is a prominent symptom, rest in a darkened room for a short time is all that is required. In simple cases where no inflammation is present, the exposure of the eyes to ordinary light should be encouraged. Send the patient away from the glare of town into the country, prohibit the use of inted glasses, which only delay the cure, and give such tonics and instruction with regard to general health as may be indicated.

Neurasthenic retinal asthenopia is sometimes an obstinate complaint.

Reflex asthenopia disappears when the cause is removed.

As prevention is better than cure, those whose eyes, by nature of their work, are exposed to glare, such as workmen exposed to electric light, should wear special glasses; the compound red and green or the dark gray glasses have been found to be most efficient.

CHAPTER XVI.

CYCLOPLEGICS.

A CYCLOPLEGIC is a drug which temporarily paralyses the ciliary muscle, and by its use we are enabled to estimate the refraction of the eye at rest. Cycloplegics are also mydriatics—that is, they paralyse temporarily the sphincter iridis and cause dilatation of the pupil.

The only cycloplegics we need concern ourselves with in refraction are **atropine** and its derivative, **homatropine**.

These drugs paralyse the sphincter iridis and the oculomotor nerve-endings in the ciliary muscle; consequently the pupil is dilated and accommodation power is reduced, or (when the full action of the drug is obtained) lost, leaving the eye adjusted for its far point and in a state of rest.

Atropine is the stronger drug, and should be used, when practicable, in all young subjects where the amplitude of accommodation is very great, as in children under 16 years; the full effect is obtained only after two or three days' use. In older patients complete cycloplegia may occur in two hours.

The effect of the drug does not begin to pass off for thirty-six hours, and the accommodation power is not fully restored until a week or ten days have passed. The pupil is restored to its normal size about the same time, sometimes a little earlier.

Homatropine has the same general effect as atropine, but differs in that its full effect on the pupil and ciliary

muscle manifests itself more promptly, and disappears much more rapidly, than atropine; but it is not so complete a paralyser of the ciliary muscle as atropine, and in young people whose accommodation is very active it is not to be relied on. On the other hand, in people over 20 years of age, it paralyses the muscles quite enough for all practical purposes when used in sufficiently strong doses and combined with cocaine.

Cocaine favours the absorption of the drug by rendering the outer epithelial layer of the cornea and the conjunctiva more pervious.

As a general rule, the full effect of homatropine is obtained in an hour. This effect begins to pass off in six hours, and the whole effect has disappeared in twenty-four or twenty-six hours. The restoration of the pupil to its normal size takes a few hours longer.

Between the ages of 16 and 20, the selection of the cycloplegic must depend on the time that the patient can give up to the examination. Always try and obtain consent for the use of *atropine* in such cases, as its effect is more reliable; but where only one day can be spared, the surgeon will have to be content with homatropine. In young subjects at school who cannot give up the time to atropine cycloplegia, homatropine should be exhibited two or three times at intervals of half an hour before the refraction is estimated, but if a satisfactory result is not obtained atropine will have to be used. One great advantage of homatropine is that it rarely, if ever, produces toxic symptoms.

The Form in which Cycloplegics should be Used.—It is impossible to know when using drops or solutions how much of the drug is absorbed and how much is wasted, and they do not keep well. Atropine in solution is liable to produce toxic symptoms by passing down the tear passages into the throat.

On the other hand, ophthalmic "tabloids" and discs have been brought to such a state of perfection that they

form the most scientific, efficient, and safe method of administering the drugs.

The most useful tabloids are: Atropine $\frac{1}{200}$ gr., and homatropine with cocaine $\frac{1}{50}$ gr. each.

Tabloids or discs should dissolve quickly when placed on the inner surface of the lower lid, and should cause little or no irritation or pain.

Atropine may also be used in the form of an ointment, the pure alkaloid being dissolved in vaseline, the proportion being gr. iv. of atropine to the ounce of vaseline. This should be put up in a small tube, and a small quantity placed on the inside of the lower lid, by means of a clean glass rod, morning and late afternoon. It should not be used on the day the examination is to be made, as the presence of the vaseline may interfere with the tests.

Cycloplegics are rarely necessary over the age of 40. The accommodation power is considerably reduced by that time, and any latent hyperopia that may have been present has become manifest.

Never use a cycloplegic should there be any suspicion of glaucoma or a tendency to glaucoma.

Make it a rule never to use atropine in patients over 25 years of age, and then there need be little fear of inducing a glaucomatous attack, because homatropine is very speedily and efficiently counteracted by eserine, and if homatropine has been used, and any suspicious symptoms arise, a tabloid of eserine ($\frac{1}{600}$ gr.) will allay all anxiety.

Cramp of the Ciliary Muscle.—This is the opposite of cycloplegia, and occurs in two forms: (1) *Clonic*, which is a temporary spasm, soon passing off with rest; (2) *Tonic*, which is a permanent spasm, referred to in the previous pages as *spasm of accommodation*, and generally associated with hyperopia in young people (see p. 88), and producing an apparent myopia. Both forms are the result of strain of the ciliary muscle, and are cured by the use of a cycloplegic and the correction of the refraction error.

CHAPTER XVII.

METHODS OF EXAMINATION—NOTE-TAKING —SPECTACLES.

Methods of Examination. — The **room** should, if possible, be sufficiently long to allow the patient to be seated 6 metres or 20 feet from the type. When this length is not obtainable (even diagonally), reversed types must be used and hung over the patient's head behind him, and opposite should be a mirror on which the type is reflected. The distance should be so arranged that the distance between the patient and the mirror and between the mirror and the type, together measure 6 metres.

Apparatus Required.—The **distant type** should be Snellen's type, and several boards with a different arrangement of letters should be used and changed as necessity arises, or they may be arranged in a box form and rotated by a cord by the surgeon from where he is standing. The change of type prevents the patient from learning the arrangement of the letters.

The type must be well and evenly illuminated, preferably by artificial light, and, if possible, in a dark part of the room, so that the difference between a bright and dark day has little or no effect on the record.

A dark room, although desirable, is not absolutely necessary; the whole consulting-room can be darkened with a blind or curtain, or a dark corner can be curtained off. *Absolute* darkness is not a *sine quâ non*.

The lighting should, if possible, be electric, and ground-glass lamps should be used, or the special high candle-power lamp made for eye or throat work, which is

mostly ground glass with a small portion clear. Failing the electric light, the "incandescent" is perhaps the best form of gas illumination.

The **reading type** should be kept clean in a cover. Both forms of type are figured at the end of the book.

The Trial Case.—This contains pairs of concave and convex spherical and cylindrical lenses, and prisms. The spherical lenses should be numbered in intervals of .25 from .25 to 4, in intervals of .5 from 4 to 8, and in intervals of 1 from 8 to 20.

The cylindrical lenses should be numbered in intervals of .25 from .25 to 3, in intervals of .5 from 3 to 6, and intervals of 1 from 6 to 8.

The prisms should be from 1° to 12°, or 14°.

The lenses should be framed.

When the surgeon does not wish to start with so expensive a set of lenses, he can manage fairly well with a single set (instead of pairs), and have the following glasses :

Sphericals : Convex and Concave.	Cylindricals : Convex and Concave.	Prisms.
.25	.25	1°
.5	.5	2°
.75	.75	4°
1	1	6°
1.25	1.25	12°
1.5	1.5	
1.75	1.75	
2	2	
2.5	2.5	
3	3	
4	3.5	
5	4	
6	5	
8	6	
10		
12		
14		
16		
20		

Such a set in a suitable case with stenopaic discs, etc., costs about £5, while the full set costs about £12.

Trial Frame.—Get a really good trial frame, regardless of cost. It should be light (made of aluminium), capable of being adjusted to fit any patient, and of being correctly centred. It should have a screw for rotating the cylinder (which can, if necessary, be used by the patient), for by this means we insure much greater accuracy in obtaining the correct angle of the cylinder. There are many bad trial frames on the market, the worst example being the rigid one supplied in most trial cases, which is practically useless.

Besides the above contents of the trial case, there should be several "blanks" to block off vision, a stenopaic slit, a pin-hole disc, and neutral tinted glasses of various shades.

Refraction Ophthalmoscope.—It is false economy to buy a cheap one. Get a good instrument to start with, and it will last a lifetime. By universal consent Morton's is the best.

Ophthalmoscope Mirrors.—A plane and a concave mirror are wanted, and these may be procured in one, each mirror serving as the cover of the other (see page 77).

Focussing Glass.—A large focussing glass as described at page 59.

Maddox Apparatus.—The test board, near test type, rod and prism (see page 43).

Perimeter.—McHardy's recording perimeter is the best, but is expensive; there are many, almost as useful, and much cheaper.

The *Ophthalmometer* is a great help, but is a luxury, and is not necessary.

Cycloplegics.—Tubes of homatropine and cocaine, āā gr. $\frac{1}{50}$; atropine, gr. $\frac{1}{200}$; and eserine, gr. $\frac{1}{600}$.

Prescription forms for spectacles are supplied by most

opticians, or they can be engraved or stamped on the surgeon's own paper, as illustrated in Fig. 79.

FIG. 79.

Mark the axis by writing the degree as indicated at page 131.

Note-taking.—The voluminous notes recommended by many authors are quite impracticable for the busy man. Fig. 80 represents a form of note-taking by means of the card system (or, if preferred, bound up in the form of a book), which will be found quite sufficient for most cases.

The Systematic Examination of the Patient.—After recording name, age, history, and symptoms, the patient is placed in the chair opposite the type, and the trial frame is adjusted. With one eye blocked you record the visual acuity of each eye separately, and also roughly the effect of concave or convex glasses. When the patient is under 16, order atropine to be put in twice a day for three or four days. On the patient's return take him straight into the dark room, examine carefully with the ophthalmoscope, and then ascertain the refraction by retinoscopy. If you have an ophthalmometer, measure the astigmatism. Then take the patient back to the type examination, find out the glass or combination of glasses that give best vision, record this, and let him return for a third and last visit when the effect of atropine has passed off, when you order the correction.

When the patient cannot return for a third visit, you

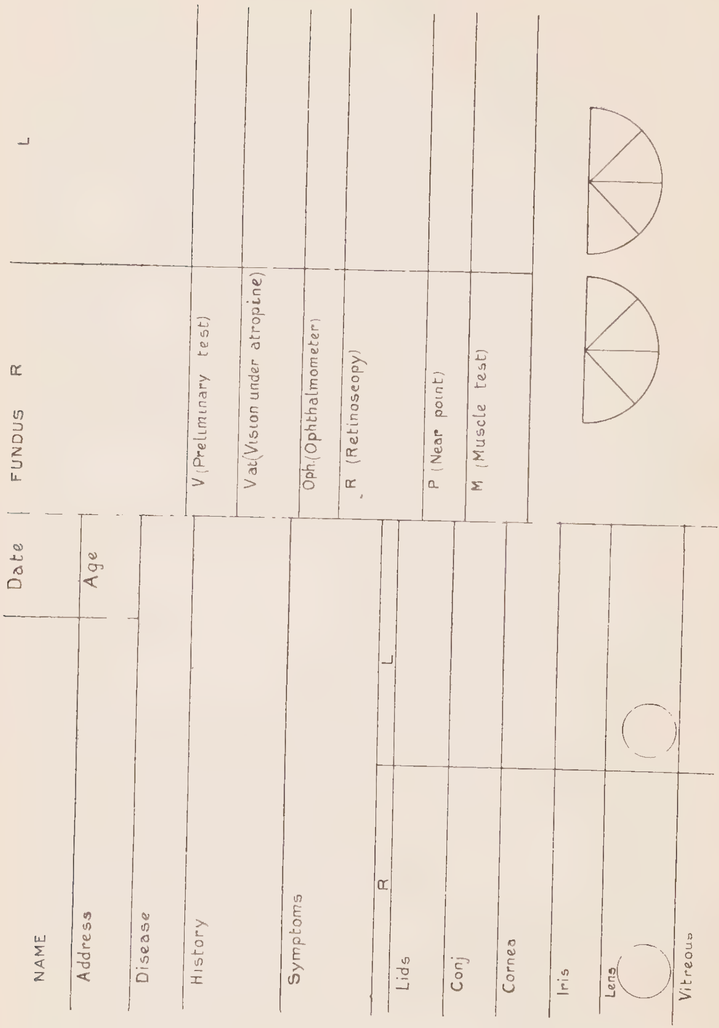

NAME
Address
Disease
History
Symptoms
R
L
Lids
Conj
Cornea
Iris
Lens
Vitreous
Date
Age
FUNDUS R
L
V (Preliminary test)
V at (Vision under atropine)
Oph. (Ophthalmometer)
R (Retinoscopy)
P (Near point)
M (Muscle test)

FIG. 80

must order the glasses according to the rules laid down in the previous chapters. When the patient is over 16 or 20 and under 30, put in Homatropine at once, wait for about an hour, and then make your examination as above (see page 184).

Over 30 and under 45 you may have to use homatropine if you do not get good results with your preliminary examination; over 45 it is rarely necessary to use a cycloplegic.

Remember that in old patients, hyperopia is often present, and is absolute; a low convex glass will often improve vision from $\frac{6}{36}$ or worse, to $\frac{6}{6}$.

In all patients over 40 near vision must also be tested and corrected, and in young patients with high hyperopia and myopia the same must be done at the last examination.

In simple presbyopia near vision only will have to be corrected. Be careful to find at what distance the patient desires to do his near work, and correct according to the rule on page 141.

Always note and record the spectacles that may have been previously worn.

If possible, always ask your patient to return and show the glasses, so that you may check them. You thus have an opportunity of not only testing the glasses, but also seeing them *on* the patient.

Spectacles—*The Centring.*—To really accurately fit, every spectacle frame should be *made for the patient*, and this should be insisted upon in every case where possible. The optical centre of the glass should coincide with the visual axis. Distance glasses should be centred for distance; working or reading glasses should be centred for the working or reading distance, and glasses ordered to be worn constantly should be centred for a point between these. We have seen that glasses have a prismatic effect if decentred. A convex glass may be

said to consist of two prisms with the bases in contact. If the glasses are too wide apart the patient looks through the inner side of the glass, which has the same effect as looking through a prism with its base outwards (see Fig. 69); consequently the convergence effort will have to be increased. If the glasses are too close together, we have the same effect as a prism with its base inwards, and the convergence effort will be diminished, the accommodation being in excess. Concave glasses may be said to be two prisms with their apices in contact, and the effect of their being out of the centre is the reverse of that of convex lenses (see Fig. 68). When these results are not desired—that is, when the lenses are not purposely

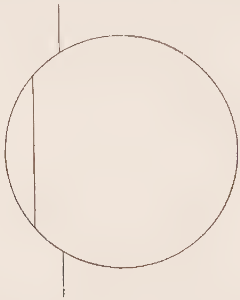


FIG. 81.

decentred—it is easy to understand how badly-fitting spectacles may be worse than useless.

To check the centring of the glasses, draw a thick vertical ink line on a piece of paper, hold the lens at a slight distance from it, and move it from side to side; when the lens is convex, the line seen through the lens will appear to move in the *opposite* direction; when concave, in the *same* direction. In Fig. 81 a convex glass has been moved to the right, and the line seen through the lens has moved to the left. By moving the lens from side to side the neutral part will be found where the lines are continuous; this is the optical centre for lateral move-

ment. Mark this point as a short vertical line on the lens with ink or a special grease pencil; now turn the lens round, and do the same with the vertical plane of the lens; where the two lines meet is the optical centre of the lens, and this should correspond with the centre of the pupil when the eyes are adjusted for the distance for which the glasses are ordered.

If a prismatic effect is desired and ordered, then the optical centre should be decentred, as explained on p. 164.

The plane of the glasses should be perpendicular to the visual axis when in use, hence reading glasses should be slightly inclined forwards.

The best form of **bridge** is the saddle-bridge; it should be flat in order not to indent the nose, and should fit the nose accurately. It is not unusual to find that the

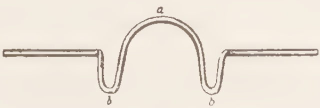


FIG. 82.

lower elbows (Fig. 82 *b*) are touching the sides of the nose, but that the upper arch (Fig. 82 *a*) is not in contact. If the bridge is not well made, the spectacles will slip.

The glasses should be as near the eyes as the lashes will permit, 13-14 mm. is the average distance, but when the lashes are very long this distance will have to be increased. It is most important to remember that the lashes *must not* touch the glass.

Note that concave glasses are weakened and convex glasses strengthened by removing them further from the eyes, and *vice versâ.*

The sides of the frames should touch the temples and pass behind the ears in all spectacles made for children,

and preferably in every case where the glasses are to be worn always. The portion behind the ear should fit comfortably, so that the wearer is hardly conscious of it.

It is always best to order *spectacles*, and not folders. Folders never fit, are rarely correctly centred, and tend to become bent, so that one or both glasses are oblique to the plane of the eyes, and one is often nearer the eye than the other.

A cylindrical lens becomes more cylindrical, and a spherical one sphero-cylindrical, by being placed obliquely before the eyes.

Under no circumstances should anyone but a presbyope be allowed to wear folders.

If spectacles are strongly objected to, rigid pince-nez may be allowed. They are made in different forms, and the selection may generally be left to the patient; they do *not* fold, are more or less rigid, and can be correctly centred.

The danger of pince-nez is that they are apt to get out of the horizontal, and if cylinders are worn this is a most serious defect. One of the chief causes of this is the dragging of the chain or cord attached to the glasses. Patients should be seriously warned of this danger.

Monocles may be allowed in cases of monocular amblyopia (see p. 149).

The glasses for children should be in strong frames.

Older patients, who have to wear the glasses always, and who can take care of them, may have the frames made as light as possible. The frames may even be dispensed with, the sides and bridge being riveted into the glasses.

Spectacles for presbyopes should have *straight* sides and be fairly strong.

The frames may be made of steel, aluminium, silver or

gold, or may be "gold-cased." Folders may be made of tortoiseshell.

When there is no reliable optician near, whom the patient can visit, the surgeon will have to give the following information with the prescription:

1. Size of lenses.
2. Inter-pupillary distance.
3. Distance between temples.
4. Height and projection of the spectacle bridge.
5. Angle of the lens.
6. Form of bridge of nose.

1. *Size of Lens.*—Glasses ordered for constant use should be of sufficient size to prevent the patient from looking over them. In young children they may be circular, or large ovals. Reading glasses should be smaller, in order that the patient can look over them. Franklin glasses should be so constructed that the upper margin of the reading portion is on a level with the lowest margin of the iris.

2. *The inter-pupillary distance* is taken by placing a rule horizontally across the nose, and measuring the distance from the internal margin of one pupil to the external margin of the other, the patient at the time looking at a distant or near point, according as the glasses are ordered for distance and constant wear, or for reading.

3. *The distance between the temples* is taken by the rule in the same way.

4. *The distance of the glasses from the eye* depends on the length of the patient's lashes; the average spot is about 14 mm. in front of the cornea. What the optician wants to know, is the relative position of the tips of the lashes and the "crown" of the nose, or, in terms of the frame, the amount of projection of the bridge. This can be found by resting a rule on the nose, and measuring.

5. *The tilting* of the lens is required only for reading glasses, and the angle of the tilt should be given.

6. *The shape of the bridge of the nose* can be well given by taking a mould in the shape of Fig. 82, with a piece of soft flat lead wire, and then by making a tracing of this on the paper.

One of the simplest and readiest plans for supplying the optician with measurement is for the surgeon to have a series of, say, six frames of different sizes and shapes, have them numbered 1, 2, 3, etc., and let the optician keep a duplicate set.

At my suggestion Mr. Dixey of New Bond Street has prepared a box containing six frames, as follows :

No.	Centres.	Front.	Bridge.				Size of Eyes.	Length of side.
			Class.	Curve.	Height.	Projection.		
1	2 (51)	$3\frac{7}{8}$ (100)	W	6	0	$-\frac{1}{8}$ (−3)	1 oval	$4\frac{3}{4}$ (120)
2	$2\frac{1}{8}$ (54)	4 (103)	C	3	$\frac{1}{4}$ (6)	0	$1\frac{1}{2}$	$4\frac{3}{4}$ (120)
3	$2\frac{1}{4}$ (57)	$4\frac{1}{8}$ (106)	W	5	$\frac{1}{8}$ (3)	0	2	$4\frac{7}{8}$ (125)
4	$2\frac{3}{8}$ (60)	$4\frac{1}{4}$ (109)	C	4	$\frac{3}{8}$ (9)	$\frac{1}{8}$ (3)	2	5 (130)
5	$2\frac{1}{2}$ (63)	$4\frac{1}{2}$ (115)	W	4	$\frac{1}{4}$ (6)	$\frac{1}{8}$ (3)	3	5 (130)
6	$2\frac{5}{8}$ (66)	$4\frac{3}{4}$ (120)	C	5	$\frac{1}{2}$ (12)	$\frac{3}{16}$ (5)	3	$5\frac{1}{2}$ (140)

The small figures in brackets under each of the inch measurements represent equivalents in millimetres.

The surgeon can then give his orders thus :

No. 4, but bridge No. 5, and sides No. 6.

Or, better, to be very exact, he can give all the details thus :

		No. of Frame.
Centre		4
Front		4
Bridge	Class	3
	Curve	4
	Height	5
	Projection	2
Size of Eye		5
Length of Side		6

This with the exact interpupillary measurement, will be found to answer admirably.

Lenses should be made of good crown glass. Pebbles (made of rock crystal), if they are good and properly cut, are much more expensive than glass; but have the advantage that they do not scratch so easily.

CHAPTER XVIII.

ILLUSTRATIVE CASES.

Simple Hyperopia.—Mrs. P., a young married woman with marked conjunctivitis and blepharitis, had used lotions, etc., with only a temporary benefit.

$$V. = \tfrac{6}{6} + .50 = \text{Hm. B.E.}$$

Under *atropine:*

$$V. = \tfrac{6}{18}\text{ part} + 1.25 = \tfrac{6}{6}\text{ B.E.}$$

No improvement c̄ cylinders.

The ophthalmometer showed *no* astigmatism.

Retinoscopy: with a plane mirror +2 gave the "point of reversal" at 1 metre.

Ordered +.75 sph. B.E.,

to be used chiefly for near work.

This patient made a good and permanent recovery.

Simple Hyperopia Heterophoria.—Mr. S., aged 25, clerk. Suffers from chronic conjunctivitis, which has been getting worse lately. Has worn glasses for distance, but never for near work.

$$V. = < \tfrac{6}{60} - 3.5 = \tfrac{6}{6}\text{ B.E.}$$

His accommodation near point is 9 cms.

$$\begin{aligned} \therefore a &= \tfrac{100}{9} - 3.5 \\ &= 11 - 3.5 \\ &= 7.5 \end{aligned}$$

His convergence near point is 18 cms. He has 1 m.a. latent divergence for distance, and 1.5 m.a. for $\frac{1}{4}$ metre (Maddox).

$$\begin{aligned} \therefore ca &= \tfrac{100}{18} - (-1) \\ &= 5.5 + 1 \\ &= 6.5\text{ m.a.} \end{aligned}$$

He was ordered −3.5 B.E., to be worn always, and he was specially instructed never to approach his work nearer than 33 cms. Some months later he returned showing great improvement. There was no heterophoria for distance, and only .5 m.a. for $\frac{1}{4}$ metre.

Hyperopic Astigmatism—Epilepsy.—Master A. B., aged 10, has had epileptic attacks for some years, with only slight benefit from medical treatment.

$$V. = \tfrac{6}{6}\text{ in both eyes.}$$

Under *atropine:*

$$\text{R.E.}\ \begin{matrix} +.25\text{ cyl. (axis vert.)} \\ +1\text{ sph.} \end{matrix} = \tfrac{6}{6} \quad \text{L.E.}\ \begin{matrix} +.50\text{ cyl. (axis vert.)} \\ +1\text{ sph.} \end{matrix} = \tfrac{6}{6}$$

The cylinders were ordered for constant use. A report, received

eight months later, stated that the boy had been perfectly well since wearing the glasses.

Hyperopic Astigmatism (Low).—Miss K., aged 26, has of late been suffering intensely from headaches, always aggravated by near work.

$$V. = \tfrac{6}{6}\ \text{B.E.} \quad \text{No Hm.}$$

Under *homatropine*

$$V. = \tfrac{6}{12} \left.\begin{array}{l} + .25\ \text{cyl. (axis vert.).} \\ + .50\ \text{sph.} \end{array}\right\} = \tfrac{6}{6}\ \text{B.E.}$$

The ophthalmometer shows .25 astig. "according to the rule"

$$\text{Ordered} \left.\begin{array}{l} + .25\ \text{cyl. (axis vert.).} \\ + .25\ \text{sph.} \end{array}\right\} \text{B.E.}$$

for all near work.

Returned some months later, and stated that the headaches had entirely disappeared.

Simple Hyperopic Astigmatism—Anisometropia.—Miss P., aged 34, complains of "dreadful headache."

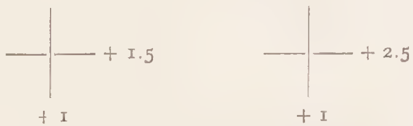
R.V. $\tfrac{6}{6}$
L.V. $\tfrac{6}{9}$

Under *homatropine* the ophthalmometer showed

R.E. .5 "according to the rule."
L.E. 1.5 "according to the rule."

Retinoscopy :

R.E. L.E.



R.V. $\tfrac{6}{12}$ + .5 cyl. (axis vert.) = $\tfrac{6}{6}$
L.V. $\tfrac{6}{18}$ + 1.5 cyl. (axis vert.) = $\tfrac{6}{9}$

The following glasses were ordered :

For distance :

R.E. + .5 cyl. (axis vert.)
− .25 sph.
L.E. + 1.5 cyl. (axis vert.)
− .50 sph.

For near work :

Cylinders only.

Note.—On returning for the final examination when the effects o the cycloplegic had passed off, it was found that the patient preferred .50 off the left and only .25 off the right. When possible, it is always best to take a little more off the stronger glass, with the

view of lessening the difference in the correction of the two eyes, at least in *one* meridian.

Simple Myopic Astigmatism.—Mr. M., aged 28. Has had migraine for some time.

$$V. = \tfrac{6}{6}\text{ B. E.}$$

Under *homatropine:* ophthalmometer shows .5 astig. "according to the rule," and vision = $\frac{6}{6}$ − .5 cyl. (axis horizontal). These glasses were ordered, and some weeks afterwards the patient reported that the migraine had disappeared.

Myopic Astigmatism (Compound).—Miss B., aged 28. Has never worn glasses. Complains of dreadful headaches.

$$V. = < \tfrac{6}{60} \text{ and } -4 = \tfrac{6}{12} \text{ B.E.}$$

Under *homatropine* the ophthalmometer showed:

R.E. 1 "against the rule."
L.E. .5 ,, ,,

$$\left.\begin{array}{l}\text{R.V.} \quad 1 \text{ cyl. (axis vert.)} \\ -3 \text{ sph.}\end{array}\right\} = \tfrac{6}{9}$$

$$\left.\begin{array}{l}\text{L.V.} -.5 \text{ cyl. (axis vert.)} \\ -3.5 \text{ sph.}\end{array}\right\} = \tfrac{6}{9}$$

These glasses were ordered for constant use, and the patient reported that the headaches disappeared.

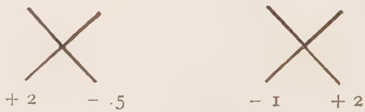
Note.—The above is also an example of anisometropia, and it is very commonly found in those cases, as above, where the difference is *not* great, that in one axis the refraction is the same in both eyes. Here the horizontal meridian is −4 in both eyes.

Mixed Astigmatism.—Miss H., aged 23, complains that her vision is very bad, and that the eyes are very painful. Never worn glasses.

$$V. = \tfrac{6}{24} \text{ in both eyes.}$$

Under *homatropine* the ophthalmometer showed 2.5 astig. oblique in both eyes.

Retinoscopy:



$$\text{R.V.} + 2.5 \text{ cyl. } 45 = \tfrac{6}{12}$$
$$- 1\ 5 \text{ sph.}$$

$$\text{L.V.} + 3 \text{ cyl. } 40 = \tfrac{6}{18}$$
$$- 2 \text{ sph.}$$

These glasses were ordered for constant use.

Note.—The patient took the exact refraction of the retinoscopy, for as the retinoscopy figures represent the point of reversal with a plane mirror at 1 metre, 1 D. must be *added* to the myopic meridian and taken off the hyperopic meridian.

Simple Presbyopia.—Mr. J., aged 52. He says his distant vision is good, but that the glasses he uses for near vision (+1) do not give him the help they did, and after reading a short time the print becomes confused, and he has to rest a short time before resuming reading.

$$V. = \tfrac{6}{6}. \quad \text{No Hm. B.E.}$$

He reads D = 0.5 well $\bar{c}$ + 2.5 sph., and the ophthalmometer shows *no* astigmatism. + 2.5 were ordered for all near work

Simple Hyperopia and Presbyopia.—Mr. E., aged 58. Has a considerable amount of conjunctivitis, from which he has been suffering for a year. Is using + 2.5 sph. B.E.

$$\begin{aligned} R.V.\ &\tfrac{6}{36} + 1.25 = \tfrac{6}{6} \\ L.V.\ &\tfrac{6}{60} + 1.5 \ \ = \tfrac{6}{6} \end{aligned}$$

The ophthalmometer shows no astigmatism. Reads D=0.5 well $\bar{c}$ + 4 sph.

He refused glasses for distance, and was ordered + 4 sph. for all near work.

Note.—It is rarely necessary to recognise the difference of .25 in glasses of this strength.

Simple Myopia and Presbyopia.—Mr. M., aged 51.

$$\left.\begin{matrix} R.V. \\ L.V. \end{matrix}\right\} = \tfrac{6}{60} - 4 = \tfrac{6}{6}$$

The ophthalmometer shows *no* astigmatism. Reads D=0.5 well $\bar{c}$ − 1.5 sph.

He was ordered the following glasses:

− 4 for distance,
− 1.5 for reading.

The patient complained of no asthenopic symptom, and his muscle test was normal.

Hyperopic Astigmatism and Presbyopia. Miss E., aged 52, complains of constant headache. Under *homatropine:*

$$R.V. = \tfrac{6}{24} \left.\begin{matrix} + .75 \text{ cyl. (axis vert.)} \\ + 1.5 \text{ sph.} \end{matrix}\right\} = \tfrac{6}{6}$$

10

$$L.V. = \tfrac{6}{24} \left.\begin{matrix} + .75 \text{ cyl.} \diagdown \\ + 1.5 \text{ sph.} \end{matrix}\right\} = \tfrac{6}{9}$$

The ophthalmometer shows astigmatism as under :

R.E. .75 acc.
L.E. .50 acc. and oblique.

With + 2.5 added to above she read D = 0.5 well.

Franklin lenses ordered for constant use, with correction as above.

Some months later patient reported that the headaches had entirely disappeared.

Note.—It will be noticed that the ophthalmometer gave in the left eye a lower correction than that which the patient preferred. This constantly occurs in oblique astigmatism, and it is probably due to the presence of a slight amount of *static crystalline* astigmatism, which, of course, the ophthalmometer cannot recognise.

Myopic Astigmatism and Presbyopia.—Mr. B., aged 46, complains of twitching of the eyelids and a strained feeling about the eyes after reading.

$$\left.\begin{array}{c}\text{R.V.}\\ \text{and}\\ \text{L.V.}\end{array}\right\} \left.\begin{array}{l}-.75 \text{ cyl. axis vert.}\\ -.75 \text{ sph.}\end{array}\right\} = \tfrac{6}{5}$$

The ophthalmometer showed astig. .75 "against the rule." He reads easily D = 0.5 with + .75 cyl. (axis horizontal).

The following glasses were ordered :

Distance :

− .75 cyl. axis vert.
− .75 sph.

Reading :

+ .75 cyl. axis horiz.

He preferred to have two pairs of glasses and *not* "Franklins."

Spasm of Accommodation.—Master W., aged 15. Has had some trouble with the eyes for six months, with headache after near work. He saw a doctor, who tested his vision without putting him under atropine, and the boy chose − 3.5 sph., which were ordered him.

$$\left.\begin{array}{c}\text{R.V.}\\ \text{L.V.}\end{array}\right\} < \tfrac{6}{60} - 1 = \tfrac{6}{6}$$

Under *atropine :*

$$\left.\begin{array}{l}\text{R.V. } \tfrac{6}{12} + .25 \text{ cyl. (axis horiz.)}\\ \qquad\quad + .50 \text{ sph.}\end{array}\right\} = \tfrac{6}{5}$$

$$\text{L.V. } \tfrac{6}{12} + .75 \text{ sph.} = \tfrac{6}{5}.$$

The ophthalmometer showed .25 astig. "against the rule" for the R.E., and *no* astig. for left. The atropine correction was ordered for all near work.

Note.—This case shows the danger of giving glasses, especially concave glasses, to young people, without using a cycloplegic. The eyestrain had produced spasm of the ciliary muscle, which masked the real condition and made him appear to be myopic.

High Myopia (Progressive ?).—Miss B., aged 17. Has been wearing for some time the following glasses:

$$\left.\begin{array}{l} -2 \text{ cyl. (axis horiz.)} \\ -10 \text{ sph.} \end{array}\right\} \text{B.E.}$$

Originally these helped her considerably in distant vision, but now they are only useful when reading, and even when using the glasses she holds her book 12 *cms.* from the eyes.

Under *atropine:*

$$\left.\begin{array}{l} \text{R.V.} -1.5 \text{ cyl. } 10 \\ \quad\;\; -18 \text{ sph.} \end{array}\right\} = \tfrac{6}{12} \text{ one letter.}$$

$$\left.\begin{array}{l} \text{L.V.} -2.5 \text{ cyl. } 20 \\ \quad\;\; -15 \text{ sph.} \end{array}\right\} = \tfrac{6}{12} \text{ one letter.}$$

The ophthalmometer shows:

R.E. 1.5 acc. and oblique.
L.E. 2.0 ,,

Retinoscopy:

The atropine correction was ordered for *constant* use, and the patient was strictly enjoined never to approach her work nearer than 33 cms.

Considering the high myopia, the fundus of both eyes was fairly normal, although marked crescents were present. Three years later with the same glasses she read the whole of $\frac{6}{12}$ and D=0.5 well at 33 cms. The eyes were again put under atropine, and the refraction was found to be practically the same as at the first examination.

Note.—This case is a marked example of the importance of preventing undue convergence in high myopia, and also illustrates the admirable result of fully correcting the error.

Aphakia.—Mrs. B., aged 56. Has cataract of both eyes, most advanced in the left.

$$\text{R.V.} = \tfrac{6}{6} + 1.5 = \text{Hm.}$$
$$\text{L.V.} \;\; \tfrac{6}{36} + 1.5 = \tfrac{6}{12}$$

Eighteen months later vision in R.E. was only $\frac{6}{12}$, and in the left it was reduced to Fingers at a metre.

Six months afterwards the left cataract was extracted, and twelve weeks after the operation,

$$\text{L.V.} < \tfrac{6}{60} + 13.5 = \tfrac{6}{6}\ 2 \text{ letters,}$$
$$\text{and } + 17 \text{ enables D} = 0.5 \text{ to be read at 25 cms.}$$

These glasses were ordered for the left eye.

Note.—The astigmatism "against the rule," so often present after cataract extraction, was absent here.

Muscular Insufficiency.—Mr. F., a clerk, aged 33, complains that in the evening after work the eyes ache and diplopia develops.

$$\text{R.V.} < \tfrac{6}{60} - 4 = \tfrac{6}{9}$$
$$\text{L.V.} < \tfrac{6}{60} - 4 = \tfrac{6}{6}$$

His convergence near point was 14 cms. The Maddox test shows 2 m.a., latent divergence at 5 metres; therefore

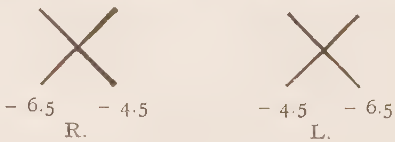
$$\begin{aligned} ca &= \tfrac{100}{14} - (-2) \\ &= 7 + 2 \\ &= 9 \end{aligned}$$

He has latent divergence of 1 m.a. at 25 cms.; -2 enables him to read comfortably at 40 cms., and he was given these glasses for near work and -4 for distance.

Muscular Asthenopia—Astigmatic Myopia.—A.E., aged 24, clerk; complains of headache and aching at back of eyes in the evening, and very often vision becomes misty, he sees double, and feels dizzy; is always better on Monday, after Sunday's rest.

He has 1 m.a. of latent divergence in both eyes (not manifest); on directing him to look at the tip of a pen the eyes converge well up to 7 cms., and then the right internal rectus suddenly gives way, and the right eye turns out.

Under *homatropine* the shadow test shows myopic astigmatism thus:



The following glasses were ordered for distance:

$$\left.\begin{array}{c}\text{R.}\\ \text{and}\\ \text{L.}\end{array}\right\}\left.\begin{array}{l}-2 \text{ cyl. (oblique)}\\ -6 \text{ sph.}\end{array}\right\}\text{giving V.} =$$

and 3 was taken off the spheric for near work.

As he was very anæmic and far from strong, he was advised to place himself under medical treatment, to take plenty of out-door exercise, never to bring his work nearer than 30 cms., and to do no near work after office hours. He returned some months later and reported that the symptoms had disappeared, and expressed himself as being "a different man."

Muscular Asthenopia—Convergence "Insufficiency"—Myopia—Anisometropia.—F. L., aged 31, a clerk, suffering from slight chronic conjunctivitis, complains of headache, chiefly frontal, coming on after work; says that lately the headache appears before he has been two hours at work.

$$V. = \begin{array}{l} R. < \frac{6}{60} - 2.5\text{ D.} = \frac{6}{6} \\ L. < \frac{6}{60} - 1\text{ D.} \quad = \frac{6}{6} \end{array}$$

His convergence near point is 18 cms.; if he is told to look at the tip of a pen at this distance, and any attempt is made to bring it nearer, the right internal rectus is seen to suddenly give way, the right eye turns considerably outwards, and diplopia supervenes. Examined by the Maddox test, he shows $\frac{1}{2}$ m.a., latent divergence for distance, and 1 m.a., which soon becomes 2 m.a., for $\frac{1}{4}$ metre. He was given a mixture of iron and strychnine, and advised to take a fortnight's rest, and on returning at the end of that time the following great improvement was noted: c P = 8 cms. Latent divergence for distance = $\frac{1}{6}$ m.a., and at $\frac{1}{4}$ metre = $\frac{2}{3}$ m.a. His range of convergence had increased from 6 m.a. to 12 m.a. He was advised to return to business, and was ordered the above correction for constant use and told not to approach his work nearer than 25 cms.

Converging Concomitant Strabismus.—Master E., aged 8. Has marked internal strabismus, which is alternating, although he most frequently fixes with the left eye.

$$\left.\begin{array}{l} R.V. \\ L.V. \end{array}\right\} = \frac{6}{5} + 1 = \text{Hm.}$$

Under atropine for a fortnight the squint entirely disappeared, and + 2 = $\frac{6}{5}$ B.E. He was given + 1 sph. for both eyes for constant use in circular frames.

A year later the atropine correction was only 1.5, and constant glass + .75 was ordered; eighteen months later the atropine correction was only + 1, and, as the squint had then entirely disappeared, glasses were discontinued.

CHAPTER XIX.

VISION TESTS FOR THE SERVICES.

THE regulations as to the standard of vision required for candidates for admission into the Services are as follows:

Army.

1. If a candidate can read D=6 at 6 metres (20 English feet) and D=0.6, at any distance selected by himself, with each eye without glasses, he will be considered fit.

2. If a candidate can only read D=24 at 6 metres (20 English feet) with each eye without glasses, his visual deficiency being due to faulty refraction which can be corrected by glasses which enable him to read D=6 at 6 metres (20 English feet) with one eye, and D=12, at the same distance with the other eye, and can also read D=0.8 with each eye without glasses, at any distance selected by himself, he will be considered fit.

3. If a candidate cannot read D=24 at 6 metres (20 English feet) with each eye without glasses, notwithstanding he can read D=0.6, he will be considered unfit.

Normal vision of one eye may be sufficient to allow a higher defect in the other, to the extent of one-sixth, if the defect is a simple error in refraction, remedied by glasses.

The candidates must be able to read the tests without hesitation, in ordinary daylight.

(N.B.—Snellen's test types will be used for determining the acuteness of vision.)

Squint, inability to distinguish the principal colours, or any morbid condition, subject to the risk of aggravation or recurrence in either eye, will cause the rejection of a candidate.

Navy.

A candidate must have no defect of sight, he must be able to read without glasses $\frac{6}{6}$ by each eye separately, and the near type at the

distance for which it is marked. Squint or any defective action of the eye muscles, any disease of the eye, and any imperfection in colour sense, disqualify.

Assistant Clerkship in the Navy.—Short-sighted candidates, in other respects fit, are especially considered; a moderate degree of refraction error would not disqualify provided the eyes are in other respects normal.

The Indian Civil Service (Covenanted and Uncovenanted), the Ecclesiastical, Education, Salt and Opium Departments.

1. A candidate may be admitted into the Civil Service of the Government of India if ametropic in one or both eyes, provided that, with correcting lenses, the acuteness of vision be not less than $\frac{6}{9}$ in one eye and $\frac{6}{6}$ in the other, there being no morbid changes in the fundus of either eye.

2. Cases of myopia, however, with a posterior staphyloma, may be admitted into the service, provided the ametropia in either eye does not exceed 2.5 D, and no active morbid changes of choroid or retina be present.

3. A candidate who has a defect of vision arising from nebula of the cornea is disqualified, if the sight of either eye be less than $\frac{6}{12}$; and in such a case the acuteness of vision in the better eye must equal $\frac{6}{6}$, with or without glasses.

4. Paralysis of one or more of the exterior muscles of the eyeball disqualifies a candidate for the Indian Civil Services. In the case of a candidate said to have been cured of strabismus by operation, but without restoration of binocular vision, if, with correcting glasses, the vision reach the above standard (1), and if the movement of each eye be good, the candidate may be passed The same rule applies to the case of unequal ametropia without binocular vision, both eyes having full acuteness of vision with glasses and good movement.

The Departments of Public Works, Forest, Survey, Telegraph, Railway, Factories, and for Various Artificers.

1. If myopia in one or both eyes exists, a candidate may be passed, provided the ametropia does not exceed 2.5 D, and if with correcting glasses, not exceeding 2.5 D, the acuteness of vision in one eye equals $\frac{6}{9}$, and in the other $\frac{6}{6}$, there being normal range of accommodation with the glasses.

2. Myopic astigmatism does not disqualify a candidate for service, provided the lens or the combined spherical and cylindrical lenses required to correct the error of refraction do not exceed 2.5 D;

the acuteness of vision in one eye, when corrected, being equal to $\frac{6}{6}$, and in the other eye $\frac{6}{9}$, together with normal range of accommodation with the correcting glasses, there being no evidence of progressive disease in the choroid or retina.

3. A candidate having total hypermetropia not exceeding 4 D is not disqualified, provided the sight in one eye (when under the influence of atropine) equals $\frac{6}{9}$, and in the other eye equals $\frac{6}{6}$, with $+4$ D or any lower power.

4. Hypermetropic astigmatism does not disqualify a candidate for the service, provided the lens or combined lenses required to cover the error of refraction do not exceed 4 D, and that the sight of one eye equals $\frac{6}{9}$, and of the other $\frac{6}{6}$, with or without such lens or lenses.

5. A candidate having a defect of vision arising from nebula of the cornea is disqualified if the sight of one eye be less than $\frac{6}{12}$. In such a case the better eye must be emmetropic. Defects of vision arising from pathological or other changes in the deeper structures of either eye, which are not referred to in the above rules, may exclude a candidate for admission into the service.

6. A candidate is disqualified if he be unable to distinguish the principal colours (achromatopsia).

7. Paralysis of one or more of the exterior muscles of the eyeball disqualifies a candidate for the service.

The Indian Medical Service and the Police Department.

1. If a candidate can read $D=6$ at 6 metres (20 English feet) and $D=0.6$ at any distance selected by himself, with each eye without glasses, he will be considered fit.

2. If a candidate can only read $D=24$ at 6 metres (20 English feet) with each eye without glasses, his visual deficiency being due to faulty refraction, which can be corrected by glasses which enable him to read $D=6$ at 6 metres (20 English feet) with one eye, and $D=12$ at the same distance with the other eye, and can also read $D=0.8$ with each eye without glasses at any distance selected by himself, he will be considered fit.

3. If a candidate cannot read $D=24$ at 6 metres (20 English feet) with each eye without glasses, notwithstanding he can read $D=0.6$, he will be considered unfit.

4. Squint, inability to distinguish the principal colours, or any morbid condition, subject to the risk of aggravation or recurrence in either eye, will cause the rejection of a candidate.

N.B.—In all other respects, candidates for these two branches of

the service must come up to the standard of physical requirements laid down for candidates for commissions in the army.

The Indian Pilot Service, and Candidates as Guards, Engine-drivers, Signalmen, and Pointsmen on Railways.

1. A candidate is disqualified unless both eyes are emmetropic, his acuteness of vision and range of accommodation being perfect.

2. A candidate is disqualified by any imperfection of his colour sense.

3. Strabismus, or any defective action of the exterior muscles of the eyeball, disqualifies a candidate for these branches of service.

The Indian Marine Service, including Engineers and Firemen.

1. A candidate is disqualified if he have an error of refraction in one or both eyes which is not neutralized by a concave or by a convex 1 D lens, or some lower power.

2. A candidate is disqualified if he cannot distinguish the principal colours and their various shades, red, green, violet or blue, and yellow.

3. Strabismus, or any defective action of the exterior muscles of the eyeball, disqualifies a candidate for this branch of service.

Special Duty.

Candidates for special duty under Government must possess such an amount of acuteness of vision as will, without hindrance, enable them to perform the work of their office for the period their appointment may last.

[I am indebted to the War Office, the Admiralty, and the India Office for the above regulations.]

Home Civil Service.

There is no fixed standard. The candidate is referred to "a competent medical adviser, leaving him to apply whatever tests he may deem suitable, and whatever standard the particular situation may require."

English Railways.

No uniform standard. Each company has its own standard.

Every engine-driver should have normal colour perception, and, without glasses, vision should be at least $\frac{6}{12}$ in each eye.

APPENDIX.

The Numbering of Lenses.—The following table shows at a glance the approximate equivalent of the old and new numeration :

Dioptres.		Inches.	Dioptres.		Inches.
0.25	......	160	5	......	8
0.50	......	80	5.50	......	7
0.75	......	52	6	......	$6\frac{1}{2}$
1	......	40	7	......	6
1.25	......	31	8	......	5
1.50	......	26	9	......	$4\frac{1}{2}$
1.75	......	22	10	......	4
2	......	20	11	......	$3\frac{1}{2}$
2.25	......	17	12	......	$3\frac{1}{3}$
2.50	......	16	13	......	3
2.75	......	14	14	......	$2\frac{3}{4}$
3	......	13	15	......	$2\frac{2}{3}$
3.50	......	11	16	......	$2\frac{1}{2}$
4	......	10	17	......	$2\frac{1}{3}$
4.50	......	9	18	......	$2\frac{1}{4}$
			20	......	2

Numbering of Prisms.—The oldest and best-known method of numbering prisms is by the angle of refraction ; thus, a prism 2° means a prism whose refracting angle is 2°. Maddox has suggested the word "prismetry" to denote the numbering by the *deviating* angle.

The Deviating Angle of a Prism.—In Fig. 83, if a ray p enter the prism, instead of passing out at p', it is refracted towards the base B C and away from the angle B A C, and is again bent towards the base on passing out, and emerges in the direction f (see p. 3). The angle $p'\ o\ f$, made by the backward

prolongation of *f* and the forward prolongation of *p*, is the *angle of deviation*, and it is equal to about half the angle of refraction.

To indicate that the angle of deviation is implied, a small *d* is added ; thus, prism 4° is approximately equal to prism 2°*d*.

Angle of Refraction.					Angle of Deviation.
[illegible]°	...	...	...	...	32′
5°	...	...	. .	...	2° 42′
10°	...	...	...	...	5° 26′

Another method of measuring prisms is that of Dennett's, and he calls his unit the *centrad* ▽. The centrad is the hundredth part of a radian, a radian being the angle subtended

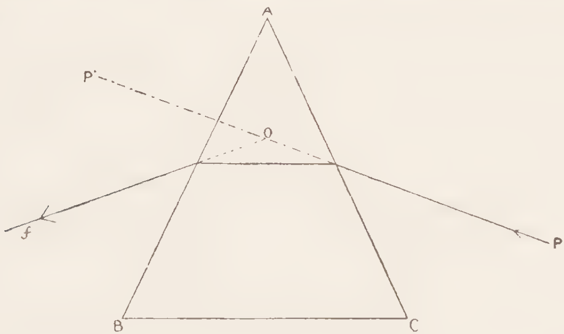


FIG. 83.

at the centre of a circle by an arc, which is equal in length to the radian. It is interesting to note that the centrad has a relative value to the metre angle, in that half the number of centimetres between the pupils indicates the number of centrads in the metre angle.

A third method is that of Prentice, who makes the unit the *prism dioptre :* P D △. 1 P D is a prism that will deflect a ray of light 1 cm. for each metre of distance, and differs from the centrad in that the latter is measured on the arc, while the prism dioptre is measured on the tangent.

The great practical use of the P D is the ease by which the decentring of lenses can be accomplished ; thus, a lens of 1 D

displaced laterally 1 cm. has the effect of 1 P D prism, and so on. The prismatic effect is that of the decentring in centimetres multiplied by the dioptric strength of the lens (Maddox).

The numbering by these three methods, viz., the old method (refracting angle), the centrad, and prism dioptre, differs very little for low degrees—in fact, for any strength used in ophthalmology—and it is only when we come to values over 20 that any practical discrepancy exists.

Centrad.	Prism Dioptres.	Degree of Refraction Angle.
1	1	1°
5	5.0045	5° 28′
10	10.033	10° 39′
15	15.114	15° 16′

In trial cases the prisms are usually cut circular, so that they can be used in a trial frame; the exact position of the base of

FIG. 84.

the prism is marked by a line on the glass at right angles to the base.

Rotating Prisms.—If two prisms of equal strength be placed in apposition in such a manner that the base of the one is in contact with the apex of the other, they neutralize each other, and if we rotate them in opposite directions we obtain the effect of an increasingly strong prism.

Risley's Rotary Prism (Fig. 84) is made on this principle. If we place it in one side of a trial frame, both eyes being used, start from zero and gradually turn the button, we can

ascertain the strongest prism the eyes can stand without having diplopia, or, if we are dealing with a case of diplopia, we can ascertain the weakest prism that will procure "fusion" vision.

The numbers on the frame indicate the refraction angle in degrees, and the instrument can give a total prismatic power of 30°.

Prisms form no images and have no foci.

INDEX.

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